National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Phenology Monitoring Protocol

Northeast Temperate Network

Natural Resource Report NPS/NETN/NRR—2013/681

ON THE COVER
Clockwise from top left: close-up of rough-stemmed goldenrod with fruits unripe; goldenrod with fruits ripe; red maple leaf in fall color at Marsh-Billings-Rockefeller NHP; and Audio Recording Unit being set up in March at Marsh-Billings-Rockefeller NHP by SCA intern Amanda Anderson.
Photographs by: Top: Boston Harbor Islands National Recreation Area, bottom: Ed Sharron

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This report is available from the Northeast Temperate Network (http://science.nature.nps.gov/im/units/netn/monitor/programs/phenology/phenology.cfm), and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

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Contents

Page

Tables vii

Executive Summary ix

Acknowledgments xiii

List of Terms and Acronyms xiii

Background and Objectives 1

Justification 1

Existing Programs 2

Pilot Project 2

Goals and Objectives 3

Sampling Design 7

Approach 7

Sampling Frame and Site Selection 8

Frequency and Replication 10

Species and Individual Selection 10

Detectable Level of Change 11

Methods 13

Field Season Preparations 13

Establishing sites 13

Sequence of Events During the Field Season 14

Making Observations 14

Automated Data 14

Data Processing 15

End of Season Procedures 15

Contents (continued)

Page

Data Management, Analysis and Reporting 17

Data Submission and Management 17

Quality Assurance/Quality Control 17

Data Analysis, Integration and Reporting 17

Personnel Requirements and Training 19

Roles and Responsibilities 19

Qualifications 19

Training Procedures 19

Operational Requirements 21

Annual Workload and Field Schedule 21

Equipment and Supplies 22

Startup Costs and Budget Issues 22

Legal Requirements 22

Literature Cited 25

Revision History 29

Appendix A. Monitored Phenophases for NETN Species 30

Appendix B. NETN Phenology Program Contact List 35

SOP 1 – Safety 37

SOP 2 – Site Selection and Setup 65

SOP 3 – Observer Recruitment and Training 73

SOP 4 – Observation 77

SOP 5 – Building an Autonomous Recording Unit 80

SOP 6 – Deployment and Maintenance of Autonomous Recording Units 93

Contents (continued)

Page

SOP 7 – Acoustic Template Creation 119

SOP 8 – Automated Sound Detection and Classification 157

SOP 9 – Selecting, Deploying and Maintaining Automated Digital Cameras 205

SOP 10 – Processing Image Data 217

SOP 11 – Data Management and Quality Assurance/Quality Control 223

SOP 12 – Data Analysis and Reporting 243

SOP 13 – Protocol Revision 253

Tables

Page

Table 1. Plant species selected for phenology monitoring in NETN designated park habitats. 4

Table 2. Animal species selected for phenology monitoring in NETN designated park habitats. 5

Table 3. Core and optional habitats for phenology monitoring within NETN parks. Core habitats are shown in bold. 9

Executive Summary

Phenology is critical to many aspects of human life and nearly all ecological relationships and processes. As global climate continues to warm and change, widespread shifts in phenological patterns are occurring across the globe, and more change is inevitable. This protocol has been developed to provide standardized methods for monitoring phenology within the National Park Service (NPS) Northeast Temperate Network (NETN), as part of the NPS Inventory and Monitoring Program (I&M). NETN encompasses the Appalachian National Scenic Trail (APPA), Acadia National Park (ACAD), the Boston Harbor Islands National Recreation Area (BOHA), and 10 national historical parks and national historic sites in the Northeastern United States.

This protocol was developed in collaboration with and relies upon the procedures and infrastructure of the USA National Phenology Network (USA-NPN), including *Nature's Notebook*, USA-NPN's online plant and animal phenology observation program (www.nn.usanpn.org). Organized in 2007, USA-NPN is a nation-wide partnership among federal agencies, schools and universities, citizen volunteers, and others to monitor and understand the influence of seasonal cycles on the nation's biological resources.

The overall goal of NETN's phenology monitoring program is to determine trends in the phenology of key species in order to assist park managers with the detection and mitigation of the effects of climate change on park resources. An additional programmatic goal is to interest and educate park visitors and staff, as well as a cadre of volunteer monitors.

Specific monitoring objectives of this protocol are to:

- Develop and maintain a list of key species that are of scientific or management interest and are suitable for phenology monitoring within NETN parks

- Detect long-term trend in timing and abundance of monitored phenophases of key species at index sites in designated core and optional park habitats

- Explore correlations between phenological data and climate variables (including mean monthly temperature and degree days) in order to develop hypotheses about impacts of climate change on phenology

We focus network-wide efforts on a short list of selected species in order to provide sufficient data to determine trends. Fifteen plant and 12 animal species occurring within two core habitats (Northern hardwood forest and Vernal pools) and five optional park habitats have been selected for phenology monitoring.

To accomplish these objectives, NETN uses three approaches: 1) park visitors are recruited on-site to submit one-time phenological observations at marked locations; 2) interested volunteers and park staff are recruited and trained to submit repeat phenological observations; and 3) automated sensors (digital cameras and audio recorders) are used to record data at select locations. In addition to collecting data at an optimal frequency, automated sensors can be used at difficult to access or sensitive sites, or can provide a useful quality assurance check when used

in conjunction with volunteer observations. Detailed standard operating procedures (SOPs) included in this protocol provide step-by-step instructions for monitoring using each approach. Pilot testing of our methods began in 2009 and continued through 2012.

We monitor phenological status and intensity or abundance using phenophases defined by USA-NPN (Appendix A), rather than the more traditional phenological event. A phenophase is a specific seasonal life history stage or behavior, such as a plant having open flowers, or a bird singing. This status-based approach is data rich—it provides information on presence, absence, and duration of phenophases. Another advantage of status monitoring is that is typically easier for citizen volunteers to interpret and record than whether or not a phenological event has occurred.

At each participating park, at least three sites are selected for phenology monitoring within each monitored habitat. Due to the reliance on volunteer monitors and the high sampling frequency needed for phenological observation, sites are selected for convenience of access and presence of monitored species, in addition to lack of human disturbance, representation of local conditions, and uniformity. This approach will allow NETN to detect temporal trends in phenological change for key species at these "index" sites. NETN assumes temporal phenological trends at index sites will be indicative of change at other locations within these park habitats. The selected "index site" design meets NETN sampling objectives to detect temporal change, while accommodating the need to monitor conveniently located sites.

Following USA-NPN recommendations, NETN observers are instructed to monitor sites at least weekly but ideally every other day when phenology is changing quickly, such as in the spring and fall. At most sites, data from multiple observers is pooled to achieve optimum frequency. This approach balances the need for frequent observations, with the recognition that volunteer monitors may not be able to participate at optimum frequency. Sites with automated cameras or audio recorders collect data frequently or continuously throughout the day, providing a data stream at optimum frequency.

For plant observations, at least three individuals of each plant species are marked and monitored at each site. Monitoring the same individuals repeatedly over time limits the influence of confounding factors, such as genotype and microclimate, that might affect observations of different individuals over time. However, it is impractical for volunteers to mark and monitor individual animals, so animal species are monitored as a population at each site.

Monitors observe and record phenological status and abundance using *Nature's Notebook* Phenophase definition sheets and datasheets. Observers may be untrained park visitors recruited by information displays during a park visit to make one-time or initial observations, or park volunteers trained to make repeat observations throughout the season. Observers upload data directly into *Nature's Notebook* (www.nn.usanpn.org).

Automated recording units are deployed in some parks to detect vocalizations of bird, amphibian and other species of interest. Raw audio files are processed using spectrogram cross correlation or binary point matching to detect and classify phenophase status. The resulting processed data set is a time series of phenophase detections.

Digital time-lapse photography is used to track seasonal development of individual plants and vegetation canopies. Park coordinators choose to use either outdoor webcams (cameras directly addressable via Internet Protocol), or plant-cams (inexpensive outdoor time-lapse cameras targeted at hobbyists). Park coordinators may process raw image files either by using specialized software (PhenoCam Image Processor or PCIP) to extract an indicator of canopy greenness; or by manually extracting flowering and other phenophase information by viewing image datasets from individual plants.

To ensure the quality of monitoring data collected in this program, we rely on standardized, written protocols and datasheets, careful training for monitors making repeated observations, and oversight by park-level coordinators. For digital data collection, we employ standardized file-naming procedures, and data imprinting on imagery for assurance that site and date metadata are correctly attached to each file. Data validation is made by comparing phenological data from multiple methods at the same site, and at related sites (i.e., similar sites at the same park). All computer data files are stored in duplicate, to guard against data loss from hard drive failure. Responsibility for data management is shared between park coordinators and the NETN Data Manager, as described in the Data Management and Quality Assurance/Quality Control SOP.

Network staff include phenology reporting within annual Weather and Climate Reports for parks participating in this program. Annual reporting will include descriptive statistics for select phenophases of monitored species. Once 10 years of data have been collected, network staff can begin to analyze and report on trends in phenology and explore correlations between phenological data and climate variables in order to develop hypotheses about impacts of climate change on phenology. Analysis is described in the Data Analysis and Reporting SOP.

This monitoring protocol requires support from network and park staff and cooperators as well as citizen volunteers. Park staff coordinate activities at each participating park, including setting up and maintaining designated sites, and recruiting volunteers. Volunteers interested in making repeat observations attend a training session held annually at each participating park and within each APPA region. Training focuses on understanding material in the NETN Phenology Observer Training Manual, and includes a brief introduction to phenology, locations of designated monitoring sites, description of monitored species and phenophases, and directions for submitting data online.

Equipment for observer monitoring is minimal. Monitoring via automated sensors requires purchase or construction of autonomous recording units (ARUs) and cameras, memory cards and other equipment.

Acknowledgments

This Protocol relies upon the methods, datasheets and online infrastructure developed by the USA National Phenology Network (USA-NPN), including *Nature's Notebook*. *Nature's Notebook* (www.nn.usanpn.org) is the online plant and animal phenology observation program of USA-NPN.

We wish to acknowledge the important contributions to this protocol made by M. Albert, who helped implement the pilot project, and by J. Gross, P. Nagler, and S. Gage, who contributed useful reviews which improved this document. Also, we acknowledge and appreciate collaborative discussions with staff of the California Phenology Project (CPP).

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Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

List of Terms and Acronyms

ACAD - Acadia National Park

APPA - Appalachian National Scenic Trail

ARU – Autonomous recording unit

BOHA - Boston Harbor Islands National Recreation Area

I&M – National Park Service Inventory and Monitoring Program

MABI - Marsh-Billings-Rockefeller National Historical Park

MIMA - Minute Man National Historical Park

MORR - Morristown National Historical Park

NETN - Northeast Temperate Network

NHP - National Historical Park

NHS - National Historic Site

NPS - National Park Service

NST - National Scenic Trail

PRA - Paperwork Reduction Act of 1995

ROVA - Roosevelt-Vanderbilt National Historic Sites

SAGA - Saint-Gaudens National Historic Site

SAIR - Saugus Iron Works National Historic Site

SARA - Saratoga National Historical Park

USA-NPN - USA National Phenology Network

USGS - United States Geological Survey
WEFA - Weir Farm National Historic Site

Background and Objectives

Phenology is "the study of the timing of recurrent biological events, the causes of their timing with regard to biotic and abiotic forces, and the interrelation among phases of the same or different species" (Lieth 1974). Phenological events include the beginning and end of flowering, leaf out, migrations, hibernation, and other similar seasonal biological events. Phenology is critical to many aspects of human life—e.g., agriculture, gardening, health, cultural events, and recreation—and nearly all ecological relationships and processes—e.g., plant-pollinator and predator-prey relationships, competition, and carbon and water cycling (Schwartz 2003).

This protocol has been developed for monitoring phenology within the National Park Service (NPS) Northeast Temperate Network (NETN), including the Appalachian National Scenic Trail (APPA), as part of the NPS Inventory and Monitoring Program (I&M). NETN is one of 32 ecoregional networks established by NPS to facilitate expanded inventory and monitoring activities. These networks monitor "Vital Signs" which are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. In addition to APPA, NETN encompasses Acadia National Park (ACAD), the Boston Harbor Islands National Recreation Area (BOHA), and 10 national historical parks and national historic sites in the Northeastern United States.

This protocol was developed in collaboration with the USA National Phenology Network (USA-NPN). Organized in 2007, USA-NPN is a nation-wide partnership among federal agencies, schools and universities, citizen volunteers, and others to monitor and understand the influence of seasonal cycles on the nation's biological resources. Participants in the network collect, share, and use phenological data, models, and related information. USA-NPN promotes broad understanding of plant and animal phenology and makes phenological data and related information freely available to scientists, resource managers and the public to aid in decision-making and adaptation to changing environmental conditions. Toward that end, the National Coordinating Office (NCO) of the USA-NPN promotes the use of standardized approaches to monitoring phenology and maintains a national phenology information management system, including *Nature's Notebook*, USA-NPN's online plant and animal phenology observation program (www.nn.usanpn.org). USA-NPN monitoring standards were developed with extensive input from participating organizations. Both the USA-NPN data infrastructure and their standardized monitoring methods have been incorporated into this protocol.

Justification

Phenology has been recognized as an early indicator of changing climate (Root et al. 2003). Phenological events respond to variation in cues such as day length, temperature, and precipitation. As the global climate continues to warm and change, widespread changes in phenological patterns across the globe continue to occur (Parmesan & Yohe 2003, Parmesan 2006), and altered phenology may have far-reaching consequences. As species respond individually to changing climate, food webs may become uncoupled and competitive relationships altered (Miller-Rushing et al., 2010). For example, migrating birds may respond differently to changing conditions than do their key food sources, and may arrive too early or too late to find enough food (Miller-Rushing et al. 2008b). Invasive exotic species may respond

favorably to changing climate conditions and outcompete native species (Willis et al. 2010). Phenology is particularly well-suited to monitoring by citizen volunteers because it is both easy to observe and engaging to the public. Phenology "is perhaps the simplest process in which to track changes in the ecology of species in response to climate change" (IPCC 2007).

Existing Programs

Several phenology monitoring programs already exist in the Northeast and nationwide. The Appalachian Mountain Club's (AMC) Mountain Watch program has been encouraging volunteer monitors to collect phenological data on alpine and forest wildflowers in the White Mountains of New Hampshire and Maine for several years, and has recently added a group of southern New England and mid-Atlantic wildflowers to their phenology program. The AMC project is a good example of how to successfully engage a hiker community. Project BudBurst (www.budburst.org) and Journey North (http://www.learner.org/jnorth/) are well-known nationwide programs which encourage citizens and students to observe and report phenological observations on plants and animals, respectively. Other nation-wide programs, such as eBird, encourage volunteers to observe and submit repeat monitoring observations and thus provide phenological data even though phenology may not be a specific program goal. In addition to these programs, there is a long history of scientists and amateurs recording phenological observations in the United States and elsewhere in the world (Schwartz 2003). These programs and historical studies used a variety of methods for monitoring phenology.

The USA-NPN seeks to create partnerships and data sharing among organizations interested in phenology, and has developed monitoring standards to facilitate the integration of data from ongoing programs, historical data sets, and newly collected data (Denny et al., submitted). By partnering with USA-NPN, we facilitate integration of NETN data with other contemporary and historical datasets.

Pilot Project

The NETN parks and network office collaborated with USA-NPN, AMC and the Appalachian Trail Conservancy (ATC) to undertake a 3-year pilot phenology monitoring project in NETN parks. Planning and data collection began in 2009 and continued through 2012. This pilot sought to:

- Implement phenology observation at NETN parks providing a template for monitoring phenology in other parks throughout the United States
- Develop methods to train staff and volunteers in monitoring techniques
- Develop methods to manage data, including collection, storage, and quality control
- Educate NPS staff, park visitors, and the broader public
- Collect data to determine long-term trends in phenology of selected species
- Determine correlations between phenological observations and climate data

The pilot tested three methods of data collection (recruiting park visitors to make one-time observations, training volunteers to make repeat observations, and training staff to make repeat observations) and primarily involved four NETN parks (ACAD, APPA, BOHA and MABI). The pilot experience helped the group better understand how phenology monitoring could be undertaken at different parks with different logistical needs and pools of potential monitors. It also served as a useful field-test of this evolving protocol. A report describing the pilot project is available on the USA-NPN website (at http://www.usanpn.org/netnproject), as are additional materials describing this collaborative pilot project.

Goals and Objectives

The overall goal of NETN phenology monitoring is to determine the trend in phenology of key species in order to assist park managers with the detection and mitigation of the effects of climate change on park resources. An additional programmatic goal is to interest and educate park visitors and staff, as well as a cadre of volunteer monitors.

Specific monitoring objectives of this protocol are to:

- Develop and maintain a list of key species that are of scientific or management interest and are suitable for phenology monitoring within NETN parks. To be suitable, a species must be readily identifiable by trained observers or by automated acoustic or photographic techniques and exhibit observable phenophases. In addition, preference is given to species with legacy data sets available for comparison.

- Detect long-term trends in timing and abundance of monitored phenophases[1] of key species at index sites in designated core and optional park habitats.

- Explore correlations between phenological data and climate variables (including mean monthly temperature and degree days) in order to develop hypotheses about impacts of climate change on phenology.

We focus network-wide efforts on a short list of selected species in order to provide sufficient data to determine trends. Fifteen plant and twelve animal species occurring within two core habitats (Northern hardwood forest and Vernal pools) and five optional park habitats have been selected for phenology monitoring (Tables 1 and 2). The list of key species will be updated periodically as new information becomes available or management focus changes.

[1] See Appendix A for monitored phenophases.

Table 1. Plant species selected for phenology monitoring in NETN designated park habitats. Core habitats and associated species are shown in **bold**. The two core habitats are widespread and ecologically important within most NETN parks.

Plant species	Lifeform	Designated habitat
Garlic mustard (Alliaria petiolata)	Forb (herb)	**Northern hardwood forest**
White wood aster (Eurybia divaricata)	Forb (herb)	**Northern hardwood forest**
Red maple (Acer rubrum)	Broadleaf tree or shrub	**Northern hardwood forest** Permanent freshwater wetland
Sugar maple (Acer saccharum)	Broadleaf tree or shrub	**Northern hardwood forest**
Marsh marigold (Caltha palustris)	Forb (herb)	Permanent freshwater wetland
Purple loosestrife (Lythrum salicaria)	Forb (herb)	Permanent freshwater wetland
Bunchberry (Cornus canadensis)	Forb (sub-shrub)	Spruce-fir forest Alpine and Subalpine
Painted trillium *(Trillium undulatum)*	Forb (herb)	Spruce-fir forest Alpine and Subalpine
Hobblebush *(Viburnum lantanoides)*	Forb (herb)	**Northern hardwood forest**
Balsam fir *(Abies balsamea)*	Conifer	Spruce-fir forest Alpine and Subalpine
Common milkweed *(Asclepias syriaca)*	Forb (herb)	Grassland
Rough-stemmed goldenrod *(Solidago rugosa)*	Forb (herb)	Grassland
Beach pea *(Lathyrus japonicus)*	Forb (herbaceous vine)	Coastline
Beach rose *(Rosa rugosa)*	Broadleaf tree or shrub	Coastline
Rockweed *(Ascophyllum nodosum)*	Seaweed	Coastline

Table 2. Animal species selected for phenology monitoring in NETN designated park habitats.

Animal species	Lifeform	Designated habitat
Spotted salamander *(Ambystoma maculatum)*	Amphibian	**Vernal pools**
Spring peeper *(Pseudacris crucifer)*	Amphibian	**Vernal pools**
Wood frog *(Rana sylvatica)*	Amphibian	**Vernal pools** Permanent freshwater wetland
Common loon *(Gavia immer)*	Bird	Permanent freshwater wetland Coastline
Great black-backed gull *(Larus marinus)*	Bird	Coastline
Bobolink *(Dolichonyx oryzivorus)*	Bird	Grassland
Bobolink *(Dolichonyx oryzivorus)*	Bird	Grassland
Red-winged blackbird *(Agelaius phoeniceus)*	Bird	Grassland
Monarch butterfly *(Danaus plexippus)*	Insect (Lepidoptera)	Grassland
Eastern tent caterpillar *(Malacosoma americanum)*	Insect (Lepidoptera)	**Northern hardwood forest**
Ovenbird *(Seiurus aurocapillus)*	Bird	**Northern hardwood forest**
Winter wren *(Troglodytes hiemalis)*	Bird	Spruce-fir Forest

To accomplish these objectives, NETN uses three approaches: 1) park visitors are recruited on-site to submit one-time phenological observations at marked locations; 2) interested volunteers and park staff are recruited and trained to submit repeat phenological observations; and 3) automated sensors (digital cameras and audio recorders) are used to record data at select locations. In addition to collecting data at an optimal frequency, automated sensors can be used at difficult to access or sensitive sites, or can provide a useful quality control check when used in conjunction with volunteer observations.

The data collected using this protocol will support the interpretation of several other NETN Vital Sign monitoring programs (Mitchell et al. 2006):

- Breeding Birds – migration and breeding phenological data will inform monitoring of population sizes, such as when to monitor, how to interpret changes in number of individuals observed, potential causes of changes in abundance, and changes in habitat relationships

- Early-Detection of Invasive Species – phenological data will inform timing of management actions and aid in identification of species most likely to become invasive in the future

- Amphibians and Reptiles – phenology can be incorporated into monitoring of amphibian population sizes, and can identify potential threats to amphibians

- Climate – phenology provides a biological indicator of change that integrates several climate variables in ways that are biologically meaningful

Sampling Design

Approach

NETN trains and supports volunteer monitors and uses automatic recording devices to collect phenological data as described herein. Using volunteers provides the dual benefit of engaging the public in natural history observation while providing a cost-efficient source of monitoring labor. Phenology is well-suited to monitoring by citizen volunteers because many phenophases are easy for the public to observe with minimal training. Data from automated sensors complement data collected by volunteers by providing data for quality assurance/quality control and by facilitating monitoring at difficult to access sites.

We monitor phenological status and intensity or abundance using phenophases defined by USA-NPN (Appendix A), rather than the more traditionally-observed phenological events. Historically, phenology has often been recorded as the timing of specific phenological events—that is, precisely defined points in the annual life cycles of plants or animals such as first and last flower or first arrival and departure of migratory animals (e.g., Sparks and Carey 1995). The utility of this approach is limited by several factors, including the lack of correspondence between a first or last "event" and the overall phenological behavior of individuals or populations (Moussus et al. 2010). The observed timing of phenological events can be affected by many factors, including population size, the size of individuals, sampling effort, and outlier effects (Tryjanowski et al. 2005, Miller-Rushing et al. 2008a, van Strien et al. 2008, Blumstein 2009). These confounding factors can make it difficult to quantify the relationship between phenology and climate or other environmental variables—in fact, they can lead investigators to draw erroneous conclusions from the data (Miller-Rushing et al. 2008a). Also, limiting monitoring to first events generally misses repeat events, such as a second flush of leaves after a defoliation event, and can be impractical for species in regions where the beginning of a season or an event is difficult to define.

Status monitoring, as defined by USA-NPN, is the evaluation of phenological status over the course of the entire year using carefully defined phenophases (Denny et al., submitted). A phenophase is a specific seasonal life history stage or behavior with a measurable duration, such as the period during which a plant has open flowers, or the period during which the males of a particular bird species can be heard singing their typical territorial song. Using this approach, observers record a plant or animal's phenological status during a series of repeat observations. Observers may also include a count or estimate of intensity or abundance associated with the phenophase. This status-based approach is data rich because it provides information on presence, absence, and duration of phenophases. The richness of the data will facilitate exploration of relationships between phenology and climate variables, comparisons between the phenologies of interacting species, and precise quantification of error (Thomas et al. 2010). By documenting the intensity or abundance of each phenophase, the data can be used to describe the temporal distribution of each phenophase (e.g., Sparks et al. 2005), which can be important for identifying potential phenological mismatches among species (Miller-Rushing et al. 2010). In addition, this approach allows integration of status and event-based data because the timing of particular phenological events can be extracted from status-based observations. However, the reverse is not true; phenological status cannot be extracted from event-based observations because they usually note only one date for each phenological event.

Another advantage of status monitoring is that interpreting and recording phenological status at any given time is typically easier for citizen volunteers, than evaluating whether or not a phenological event has occurred on a particular date. Many studies have shown the value of phenological observations made by non-scientists (for example, Gazal et al. 2008, Howard and Davis 2009). There are, however, species that are inappropriate for volunteers to monitor because they are difficult to identify or are dangerous—e.g., rattlesnakes and bears. Additionally, some phenophases—e.g., the instars of some insects, breeding of secretive species—are difficult for untrained observers to monitor. Thus, we will follow USA-NPN recommendations for phenophases to observe; these recommendations include consideration of difficulty and level of expertise needed.

Automated monitoring using inexpensive time-lapse cameras can provide a more complete observational record of individual plants at a subset of sites (Crimmins and Crimmins 2008), and also allows for automated detection of certain phenophases at the individual and stand scales (Richardson et al. 2009). When cameras are focused on individuals that are also the focus of volunteer observations, the photographs can serve as a quality control check on the volunteers. Automated camera monitoring requires equipment (cameras, batteries, and memory cards), as well as staff or volunteer time to test, deploy, check, download data, and manage data. Individual parks must determine whether they want to implement camera monitoring based on their available funding, expertise, and interests.

Automated audio monitoring with autonomous recording units (ARUs) is well-suited to capturing the breeding phenology of vocal anurans (frogs and toads), songbirds, and some insects, as well as trends in the general soundscape (Kasten et al. 2012). ARUs collect data at a subset of phenology sites, providing a detailed acoustic record for the site. These recordings can be reviewed by experts to identify species, but this approach is time consuming. NETN uses automated methods to identify indicator species whose vocalizations are well-suited to automatic detection. The recordings are retained in case "detectors" for additional species are added in the future, and for potential evaluation by experts for additional species. Two options for ARUs are available in this protocol: building home-made ARUs and using commercial ARUs (the Wildlife Acoustics Song Meter). Home-made ARUs are a fraction (generally less than a quarter) of the cost of a commercial ARU, and can serve as an excellent project for high school students that integrates physics, electronics, and ecology. The drawback for these units is a less robust microphone and limited scheduling options. Commercial units like the Song Meter come ready to use, and have more flexible recording options, more robust microphones, customer support, and a generally higher reliability. The drawback for these units is the cost (about $600, without memory cards or batteries). Parks that are interested in using ARUs may choose which ARU option they want to deploy.

Sampling Frame and Site Selection

Phenology monitoring occurs in NETN parks where resource management staff are able to coordinate monitoring activities for their park. Some level of phenology monitoring has occurred in nine NETN parks: ACAD, APPA, BOHA, Marsh-Billings-Rockefeller National Historical Park (MABI), Morristown National Historical Park (MORR), Roosevelt-Vanderbilt National Historic Sites (ROVA), Saugus Iron Works National Historic Site (SAIR), Saratoga National Historical Park (SARA), and Weir Farm National Historic Site (WEFA). The remaining NETN

parks – Minute Man National Historical Park (MIMA) and Saint-Gaudens National Historic Site (SAGA) – may choose to participate in the future.

Within each park, monitoring occurs at select sites in core or optional habitats designated for phenology monitoring (Table 3). The two core habitats (vernal pools and northern hardwood forest) are monitored at all NETN parks except BOHA and SAIR which do not contain those habitats. In addition, park staff may choose to monitor optional habitats occurring in that park.

Table 3. Core and optional habitats for phenology monitoring within NETN parks. Core habitats are shown in bold.

	ACAD	APPA	BOHA	MABI	MIMA	MORR	ROVA	SAIR	SAGA	SARA	WEFA
Vernal pools	x	x		x	x	x	x		x	x	X[1]
Northern hardwood forest	x	x		x	x	x	x		x	x	x
Spruce-fir forest	x	x									
Alpine and subalpine		x									
Grassland and Open Field	x		x		x	x	x			x	x
Permanent freshwater wetland	x						x	x			
Coastline	x		x								

[1]WEFA does not have true vernal pools, but does have pools where amphibians breed.

At each site, multiple methods may be used, and multiple observers may contribute observations. Automated monitoring occurs at sites which are also observed by volunteer monitors; this provides a useful quality control check on volunteer observations. However, sensitive or difficult to access sites may be monitored by automatic recording only.

Due to the reliance on volunteer monitors and the high sampling frequency needed for phenological observation, sites are selected for convenience of access and presence of monitored species, in addition to lack of human disturbance, representation of local conditions, and uniformity. This approach will allow NETN to detect temporal trends in phenological change for key species at these "index" sites. NETN assumes temporal phenological trends at index sites will be indicative of change at other locations within these park habitats. However, it will not be possible to extrapolate data from these index sites to other locations using this non-random sample design. This is a significant limitation of the selected sample design, but one which is warranted in this case. The selected "index site" design meets NETN sampling objectives to detect temporal change, while accommodating the need to monitor conveniently located sites.

NETN follows USA-NPN recommendations for site selection with some modifications, as described in the Site Selection and Setup SOP. Sites are limited in size to be no larger than a MODIS pixel (e.g., 6 hectares or a 250-m square) but will typically be much smaller as described in the SOP. At BOHA, an island may be considered a single site.

Frequency and Replication

Variability in the timing of phenophase occurrence within individual plants in a population can exceed differences among populations (Brugger et al 2003, Goulart et al. 2005). However, differences in site conditions affecting temperature and exposure (altitude, slope, aspect, and nearby development) influence phenophase occurrence, so we monitor multiple sites at each park.

At each park, at least three sites are selected for phenology monitoring within each monitored habitat. A site is the area which is searched for one or more monitored animal species, and which encompasses selected plants of one or more species. Typically, sites are selected and setup by program staff or collaborators. However, in some cases volunteers may collaborate with park staff to identify sites that are both convenient and appropriate for monitoring.

An analysis of multiple sites and methods is underway at ACAD to help determine the best number of sites, individual plants and automatic recorders for monitoring phenology in these parks.

The effects of sampling frequency on the detection and estimation of trend in phenology depends on the shape of the temporal distribution of the phenophase in question and the magnitude of the change that is actually occurring (Miller-Rushing et al. 2008a, Moussus et al. 2010). Ideally, monitoring every second day will maximize the ability to detect and accurately estimate change. There is a substantial drop in the ability of data sets to reflect actual changes taking place when observations are made less frequently than once per week (Miller-Rushing et al. 2008a, Moussus et al. 2010).

Following USA-NPN recommendations, NETN observers are instructed to monitor sites at least weekly but ideally every other day when phenology is changing quickly, such as in the spring and fall. At most sites, data from multiple observers is pooled to achieve optimum frequency. This approach balances the need for frequent observations, with the recognition that volunteer monitors may not participate at optimum frequency.

Sites with automated cameras are monitored regularly throughout the day. Sites with audio recorders are monitored hourly or continuously depending upon the species and phenophases of interest (see Deployment and Maintenance of Autonomous Recording Units SOP for details).

Species and Individual Selection

NETN has developed a list of key species recommended for phenology monitoring in NETN parks (Table 1 and 2). To be suitable, a species must be readily identifiable by trained observers or by automated acoustic or photographic techniques and exhibit observable phenophases. In addition, preference is given to species with legacy data sets available for comparison. To be selected, a species must be found within a designated core or additional selected park habitat, and be of scientific or management interest in one of these categories:

- Foundation species (dominant primary producers, such as trees and shrubs) which provide habitat for other species and exert large influence on the system

- Invasive species and insect pests, which may be particularly responsive to climate change

- Species vulnerable to phenological mismatch, such as animal pollinated plants and their pollinators, migratory or diadromous (migratory between salt and fresh waters) species and their key food sources, and coevolved species

- Species with critical early spring phenophases, such as spring wildflowers and amphibians

- Species of special interest to park managers or visitors

This list of key species will be updated periodically, as new information becomes available. Staff at participating parks choose species from the recommended list that are of interest and present in accessible locations at their park. As a guideline, NETN suggests each park focus on only four or five key species per park in order to obtain a sufficient number of observations per species, focusing first on key species in core habitats.

For plant observations, individual plants are marked and observed as described in the Site Selection and Setup SOP. At least three individuals of each plant species are monitored at each site, in order to document variability in phenophase occurrence within the population. Variability within individuals in a population can exceed variation among populations (Brugger et al. 2003, Goulart et al. 2005).

Monitoring the same individuals repeatedly over time offers several advantages over monitoring a population. Most importantly, it limits the influence of confounding factors, such as genotype and microclimate, that might affect observations of different individuals over time. Additionally, sampling multiple individuals in a population will allow us to draw statistical inferences about the population. Individual plants are selected following USA-NPN guidelines. These include selecting plants that appear to be healthy, undamaged, and free of pests and disease. When selecting multiple individuals of a species at a single site, we select individuals that are growing in a similar environment but are not direct neighbors, in order reduce the likelihood that selected individuals are genetically identical.

Animals are not monitored as individuals. It is impractical for volunteers to mark and monitor individual animals, so animal species are monitored as a population at each site as described in the Observation SOP.

Detectable Level of Change

A power analysis is underway to better understand detectable level of change using this protocol. Multiple observations by multiple observers and multiple methods are underway at ACAD, in order to improve methods dictating replication and sample size.

Methods

Field Season Preparations

Prior to the commencement of the field season each year, NETN staff communicate with USA-NPN NCO staff to obtain any updates to phenophase definitions, datasheets or the online interface for the coming season. NETN staff provide any relevant updates to participating park staff. When possible, the NETN Science Communication Specialist updates training materials, and hosts an annual training at each participating park during annual park visits. Alternatively, staff at each participating park or APPA region plan a training session for new and returning volunteers at the start of the field season.

In the early spring each year, park staff review designated monitoring sites, selected individual plants and walking routes. This review ensures that sites and plants still meet selection criteria as described in the Site Selection and Setup SOP and that sufficient numbers of sites and individual plants of each species are selected. Site and plant marking is updated or replaced as needed. Park staff or cooperators re-deploy and field-test all automated equipment (cameras and audio recorders) in use at that park.

Establishing sites

It is critical that each monitoring site and monitored plant be marked with a unique identifier. In cases when multiple observers are monitoring the same site or plant, this unique identifier will be used to combine observations. Following the guidelines outlined in the Site Selection and Setup SOP, staff at each participating park establish specific procedures for marking sites and plants that are aesthetically acceptable at that park. These marking procedures are used by park staff and cooperators to establish designated sites for multiple observers and automated sensors.

Information describing each site is collected prior to the commencement of monitoring as described in the Site Selection and Setup SOP. This information is collected during site setup by the park staff or cooperators. Site information is updated annually, or if conditions change. Park staff setup and maintain "shared sites" (for trained observers and/or automated sensors) and "public sites" (for any site at which untrained observers will submit data) on the *Nature's Notebook* website, to allow multiple observers to submit observations at designated park sites, as described in the Site Selection and Setup SOP.

Individual plants are selected and marked for observation by park staff and by volunteer monitors if allowed at that park, as described in the Site Selection and Setup SOP. Park staff confirm correct species identification of all monitored plants.

At some designated monitoring sites, informational displays may be used to attract park visitors to make one-time or initial observations. Poster displays and/or handouts provide USA-NPN information on the species and phenophases to be monitored at that site, and *Nature's Notebook* datasheets are provided. These materials are self-explanatory to enable one-time observers to make a contribution without training. These sites must be designated as "public sites" in *Nature's Notebook* to allow park visitors to submit data online.

Sequence of Events During the Field Season

Once the field season begins, staff at each participating park or APPA region support volunteer monitors. Observers create accounts online in *Nature's Notebook* (www.nn.usanpn.org), and download a *Nature's Notebook* datasheet package, including Phenophase Definitions sheets for each monitored species. Observers visit their sites every other day during periods of rapid change, if possible, but not less than weekly. Observers record data onsite using datasheets, and then submit data online into *Nature's Notebook* as described in the NETN Phenology Observer Training Manual.

Park staff or specially trained volunteers maintain automated equipment and download data at regular intervals as described in the SOPs.

Making Observations

At each site, individual plants and animal populations are observed for phenological status and intensity or abundance using phenophases defined by USA-NPN (Appendix A) as described in the Observation SOP. During each visit, monitors record one of these options for each phenophase:

- **y** – if the phenophase ***is*** occurring
- **n** – if the phenophase ***is not*** occurring
- **?** – if observer is uncertain whether the phenophase is occurring

If observers did not check for a particular phenophase, they are instructed to not choose any of the three options and leave the phenophase blank. For most phenophases, observers also record intensity or abundance using quantitative measures defined by USA-NPN. Instructions for recording intensity or abundance are included on *Nature's Notebook* Phenophase Definitions sheets. Abundance is recorded as an actual count in some cases, or as an estimate, a percentage, or a class variable in others, as specified in the USA-NPN Phenophase Definition sheet for that species. For example, if birds are seen feeding, then observers count and record the actual number of birds seen. If a plant is in flower, then observers estimate and record the number of flowers and flower buds seen on that individual plant as one of several quantitative classes. If frog calling is heard, then observers estimate and record abundance within one of three classes: (1) individuals can be counted, there is space between calls; (2) calls of individuals can be distinguished but there is some overlapping of calls; and (3) full chorus, calls are constant and overlapping.

For plants, observations are made on marked individuals. For animals, observers look and listen for the target species during a walk along a designated transect through the site. The standard search time will vary among sites, as designated by park staff.

Automated Data

Automated recording and digital time-lapse photography are an important data source for long-term phenological research, providing a consistent and objective stream of data at optimal frequency in both accessible and remote locations. Autonomous recording units (ARUs) may be

used to detect vocalizations of many species of interest including bird, amphibian, insect and bat species; detection of these vocalizations is indicative of migratory and reproductive phenophases. Two types of ARUs are deployed in participating parks: 1) Song Meter recording units produced by Wildlife Acoustics, Inc., and 2) an inexpensive homemade ARU, designed by Jon Katz and Corinne Brauer, containing an Olympus digital recorder. Song Meter units are programmed to record hourly for a 10 minute interval or continuously, depending upon the species and phenophases of interest. Olympus units have limited programming options, and are set to record continuously. Units are visited at regular intervals for maintenance and data collection, as described in the Deployment and Maintenance of ARUs SOP.

Digital time-lapse photography is used to track seasonal development of individual plants and vegetation canopies. Two types of automated camera may be deployed in participating parks: 1) outdoor webcams (cameras directly addressable via Internet Protocol), and 2) plant-cams (inexpensive outdoor time-lapse cameras targeted at hobbyists). Cameras are programmed to capture images regularly during daylight hours, as described in the Selecting, Deploying and Maintaining Automated Digital Cameras SOP. Plant-cams are visited regularly for maintenance and data collection.

Data Processing

As soon as possible after collection, raw data files from plant-cams are renamed, as described in the Data Management and Quality Assurance/Quality Control SOP. Renaming incorporates critical information directly into the filename to help ensure accurate data stewardship.

Prior to data processing, audio data files are subsampled (if necessary), and renamed using an automated procedure to obtain an hourly subsample, as described in the Automated Sound Detection and Classification SOP. Only the subsampled data is saved and processed; the remainder of the raw data files is discarded.

Each season, park coordinators process audio files using an automated procedure operating within the R statistical environment, as described in the Automated Sound Detection and Classification SOP. This procedure uses spectrogram cross correlation or binary point matching to detect and classify phenophase status for species of birds, frogs and other taxa. The resulting processed data set is a time series of phenophase detections.

Park coordinators may process raw image files using two methods: 1) PhenoCam Image Processor (PCIP) is used to extract red-green-blue (RGB) color channel information which can be expressed as an indicator of canopy greenness (g_{cc}); and 2) flowering and other phenophase information may be manually extracted from image datasets aimed at individual plants. Details of both procedures are provided in the Processing Image Data SOP.

End of Season Procedures

In some cases, observation may continue year-round. However, for most sites, the field season will end in late fall. After conclusion of the field season, park staff or cooperators will collect automated equipment to be repaired if needed and stored for the winter. Site, route and individual plant marking is reviewed and replaced if necessary to ensure these exact locations can be found the next year. Park staff follow-up with volunteers to ensure that all data have been

submitted, and to solicit feedback to guide future monitoring. During the off-season, network staff prepare and send an annual Resource Brief to all participating volunteers. This Brief provides a descriptive summary of the annual implementation, and any preliminary results of interest.

Data Management, Analysis and Reporting

Data Submission and Management

This protocol collects three types of raw data: tabular observations, digital audio files, and digital image files. Observation data are submitted directly by observers to the National Phenology Database via USA-NPN's online interface, *Nature's Notebook* (www.nn.usanpn.org). Entries into *Nature's Notebook* are stored in the National Phenology Database and are freely available for others to access. The data may also be viewed in visualizations available online.

Maintaining accurate, standardized, and informative file names plays a pivotal role in managing the large number of digital files generated by the implementation of this protocol. Naming conventions for raw data files are described in the Data Management and Quality Assurance/Quality Control SOP.

All computer data files are stored in duplicate, to guard against data loss from hard drive failure. For most data, this is accomplished by storing identical (mirrored) copies on two separate external hard drives. For raw image files, this is accomplished by storing one copy on an external hard drive and a second copy on the PhenoCam server. Processed data files from automatic recorders are stored by the NETN data manager until those files can be submitted to the National Phenology Database via *Nature's Notebook*. Responsibility for data management is shared between park coordinators and the NETN Data Manager, as described in the Data Management and Quality Assurance/Quality Control SOP.

Quality Assurance/Quality Control

To ensure the quality of monitoring data collected in this program, we rely on standardized, written protocols and datasheets, careful training for monitors making repeated observations, and oversight by park-level coordinators. For digital data collection, we employ standardized file-naming procedures, and data imprinting on imagery for assurance that site and date metadata are correctly attached to each file. Quality assurance and quality control (QA/QC) methods are described in the Data Management and Quality Assurance/Quality Control SOP.

Data validation is made by comparing phenological data from multiple methods at the same site, and at related sites (i.e., similar sites at the same park). Data collected by untrained and trained volunteers, and from automated cameras and audio recorders will be compared to identify possible bias introduced by method, by training or lack or training, by frequency of collection, and by species or phenophase observed.

Data Analysis, Integration and Reporting

Network staff obtain data from USA-NPN at regular intervals, but no less often than annually. Analysis for each monitored species will include linear regression to determine:

- Change in selected phenophases over time (days/year or days/decade)

- Change in selected phenophases per unit of temperature (days/°C or days/growing degree day)

Network staff include phenology reporting within annual Weather and Climate Reports for parks participating in this Phenology Program. Annual reporting includes descriptive statistics for

select phenophases of monitored species. After 10 years of data collection, network staff begin analyzing and reporting trends in phenology and explore correlations between phenological data and climate variables in order to develop hypotheses about impacts of climate change on phenology. Analysis is described in the Data Analysis and Reporting SOP.

Personnel Requirements and Training

Roles and Responsibilities

This monitoring protocol requires support from network and park staff and cooperators as well as volunteer observers. At the network level, a program leader should provide overall program coordination as well as data analysis and reporting. The NETN Science Communication Specialist provides training materials, and when possible, hosts training sessions during annual park visits. The NETN Data Manager obtains network data from the USA-NPN database each year.

Park staff coordinate activities at each participating park, including setting up and maintaining designated sites and walking routes, and recruiting volunteer observers. Deployment, maintenance and data collection from automated recording devices may be performed by network staff, cooperators or park staff, or volunteers, depending on staff availability and volunteer abilities. Trained volunteer observers provide the majority of labor making observations and submitting data online, and in some cases, may assist with other tasks.

Qualifications

At the network level, a program leader overseeing program coordination and data analysis needs a background and experience in ecological field methods and data analysis, and should have hands-on experience collecting data using this protocol. In order to provide training, the NETN Science Communication Specialist must be familiar with the specific methods used herein, and have experience explaining scientific concepts to park volunteers. The NETN Data Manager should become familiar with the USA-NPN database and interface, as well as the legal requirements pertaining to this dataset.

At the park level, a coordinator at each participating park or APPA region must have good working knowledge of park habitats and the specific species monitored by this protocol. Park coordinators must be able to confirm correct identification of all monitored species. Ideally, park coordinators would also have experience organizing park volunteers.

Deployment, maintenance and collection of data from automated recording devices requires some level of technical ability and familiarity with relevant SOPs from this protocol.

The majority of monitoring observations are collected by volunteers. This program offers three levels of volunteer engagement, allowing participation by a wide range of potential volunteers. First, park visitors are recruited on-site to submit one-time or initial observations. Second, interested volunteers are trained to submit repeat observations. This level requires a moderate (at least weekly) time commitment, some familiarity with plant identification and observation, and the ability to keep careful records. Third, volunteers with technical skills and interest may be trained to assist with maintenance or data collection from automated recording devices.

Training Procedures

Volunteers interested in making repeat observations attend a 1- to 3- hour training session held annually at each participating park and within each APPA region. When possible, the NETN Science Communication Specialist will host this training during annual park visits. Training

focuses on understanding material in the NETN Phenology Observer Training Manual, and includes a brief introduction to phenology, locations of designated monitoring sites, description of monitored species and phenophases, and directions for submitting data online, as described in the Observer Recruitment and Training SOP.

Operational Requirements

Annual Workload and Field Schedule

The annual workload for NETN phenology monitoring will depend upon the number of parks participating, as well as the number of volunteer observers recruited to observe at each park. The following is a plausible workload scenario based on moderate participation at most NETN parks. However, as the program develops, this workload scenario should be updated to reflect actual time spent.

- Project leader – 0.17 Full Time Equivalent (FTE) or 8 weeks. This includes time participating in pre-season preparation and park coordination, as well as annual data analysis and reporting.

- Park coordinator– 0.05 FTE or 2 weeks. This includes recruiting and providing logistical support to volunteers, and identifying and marking monitoring sites, walking routes and individual plants.

- NETN Data Manager – 0.05 FTE or 2 weeks. This includes obtaining and archiving NETN park phenological data from the USA-NPN database, and participating in the annual operational review.

- NETN Science Communication Specialist – 0.07 FTE or 3 weeks. This includes updating annual training materials and providing trainings at participating parks during annual park visits.

- Park Volunteers – 1 – 2 hours per week during season of observation (potentially March to November). This includes time spent traveling to observation sites, observing, and submitting data online into *Nature's Notebook*.

The following is a rough schedule of events for annual monitoring activities:

- January – Completion of prior year data analysis and reporting. Discussion with USA-NPN's NCO staff to obtain any updated procedures or online interface.

- February – Begin field season planning. Update methods and training materials. Schedule training sessions.

- March – Park coordinators visit designated sites and update marking. Deployment of automated recording devices may occur. Monitoring by automated devices and returning observers may begin.

- April – June. A training session occurs at each participating park and APPA region. Monitoring by automated devices and observers continues. Observers submit data online into *Nature's Notebook*.

- July – November. Monitoring by automated devices and observers continues. Observers submit data online into *Nature's Notebook*. Park coordinators solicit feedback from

volunteer observers. NETN Data Manager obtains park dataset from USA-NPN database. Annual operational review occurs, and protocol is updated as needed.

- December. Data analysis is underway.

Equipment and Supplies

Phenology observation by monitors requires only plant marking equipment (at parks allowing volunteers to select and mark plants) and information and data sheets (available for download online at the *Nature's Notebook* website). In addition, a clipboard may be helpful, and binoculars are recommended for some phenophases, such as leaves or birds high in trees. Downloading data sheets and online submission requires access to a computer with an internet connection. Most volunteers will have access to these minimal requirements on their own. Participating parks can opt to make datasheets or binoculars available to volunteer monitors if they wish.

Monitoring via automated sensors requires additional equipment (plant-cams, webcams and/or audio recorders) and infrastructure, as described in the SOPs.

Startup Costs and Budget Issues

Startup costs are minimal due to the use of volunteer monitors and the data-infrastructure of the USA-NPN. However, startup funds are needed for automated recording devices (about $100 per plant-cam, $500 - $1,000 per webcam, $250 for parts to build an Olympus audio recorder unit, and $1,250 for a Song Meter audio recorder).

Legal Requirements

Collection of data from the public by federal agencies or their partner organizations is regulated by the Paperwork Reduction Act (PRA) of 1995. The PRA establishes information policies for data collection and is intended to reduce the amount of paperwork that agencies can request the public to submit. The PRA applies to surveys of the general public, and does not apply to other data collection by agency staff or volunteers. For the purposes of the PRA, a volunteer is someone who would be covered by Worker's Compensation if they are in an accident while assisting the agency (so NPS VIP's are "volunteers" while other park visitors are not). The trained volunteers participating in this protocol are covered by Worker's Compensation, and thus are excluded from the PRA. The PRA also does not apply to data collection from fewer than 10 participants. Thus, for this protocol, the PRA would apply only to instances where 10 or more park visitors were recruited to make one-time phenological observations using the same questions or data form design.

To comply with the PRA, approval must be obtained from the Office of Management and Budget (OMB) prior to data collection, and renewed every 3 years. In August 2012, OMB granted USA-NPN authorization for phenological data collection from the public. Any member of the public working on NPS land or at the behest of NPS, who is not a VIP, is covered under this programmatic permission.

In addition, the Privacy Act governs the collection, maintenance, disclosure of information from or about identifiable individuals that is maintained in systems of records by federal agencies. This Act prevents the disclosure of such personal information without written consent of the

subject individual. In order to comply with the Privacy Act, data received by NETN from USA-NPN does not include personal information.

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Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
0.00	July 2008 draft	Geri Tierney	Initial draft for APPA	
1.00	June 2010 draft	Geri Tierney, Abe Miller-Rushing, Brian Mitchell, Fred Dieffenbach	Expanded to encompass NETN. Revised to Oakley et al. standards. Aligned with USA-NPN protocol. Description of pilot study, SOPs for automatic recording, and legal requirements included. Starting in 2011, monitoring will include measure of phenophase abundance.	Program has expanded and developed.
1.01	Sept 2010 draft	Geri Tierney	Adjusted procedure for one-time observation. Updated goals and objectives. Updated Appendix E and F. Editorial changes.	
1.02	Oct 2010 draft	Geri Tierney	Adjusted observation definitions to match NPN change. Clarified upper limit on site size.	
1.03	Nov 2010 draft	Geri Tierney, Adam Kozlowski	Clarification of legal requirements and collection of personal information. Editorial comments	
1.04	Dec 2010 draft	Geri Tierney	Added Repeat Panorama SOP, noted that availability of legacy data is preferable in species selection, added priority habitat and ecotone language to objectives, suggest parks focus on only 4-5 key species.	Based on discussions at our Fall 2010 NERPN meeting.
1.05	April 2011 draft	Brian Mitchell, Geri Tierney	Added additional sections to match I&M standards (Oakley et al.). Adjusted list of SOPs to include automatic recording SOPs. Inserted table of priority park habitats with selected key species. Removed option for volunteer to choose custom site. Adjusted number of sites per park habitat to be >= 3, and number of individual plants per site to be >=3. Eliminated App. B and added	Based on Brian's comments and discussions with Abe Miller-Rushing and Fred Dieffenbach

			App. F. Editorial changes.	
1.10	Spring 2012 draft	Geri Tierney	Added sections describing automatic recording. Adjusted text to remove untrained observer method. Added to author list. Reordered appendices. Removed repeat photography SOP – this is now an option referenced in camera SOPs. Updated sample size section. Updated methods for 2012 to match US NPN changes. Selected black-backed gull as recommended species. Added Safety SOP.	
1.20	Sept 2012	Geri Tierney	Revised author list. Added acknowledgements. Removed target time for animal search. Numbered SOPs. Formatting and editorial changes. Moved Observer Manual to accessory doc.	
1.21	Jan 2013	Geri Tierney	Reinserted untrained observer method. Updated sections on automated sensors and data management. Added Executive summary.	
1.22	Jan 2013	Ellen Denny, Geri Tierney	Edited references to USA-NPN. Clarified monitoring frequency. Added overview of full acoustic data process. Clarified PRA, Privacy Act compliance. Split Automated Sound Detection into 2 SOPs (with separate SOP for Template Creation).Editorial changes.	Every other day monitoring is only needed during periods of rapid change.
1.30	May 2013	Geri Tierney, Brian Mitchell Ed Sharron	Editorial changes.	Response to review and formatting changes.

Appendix A. Monitored Phenophases for NETN Species

NETN monitors phenology using phenophases defined by the USA National Phenology Network (USA-NPN). These phenophases vary by species lifeform and were revised by USA-NPN for 2012. During pilot seasons, NETN monitored phenophases recommended by USA-NPN at that time, which differ from those shown here. Specific definitions of each phenophase are found on species' information sheets, which are available for download from the *Nature's Notebook* website (www.nn.usanpn.org).

Table A.1. Monitored phenophases for deciduous trees and shrubs.

USA-NPN Phenophase	Red maple	Sugar maple	Hobblebush	Beach rose
Breaking leaf buds	x	x	x	x
Leaves	x	x	x	x
Increasing leaf size	x	x	x	x
Colored leaves	x	x	x	x
Falling leaves	x	x	x	x
Flowers or flower buds	x	x	x	x
Open flowers	x	x	x	x
Pollen release	x	x		
Fruits	x	x	x	x
Ripe fruits	x	x	x	x
Recent fruit or seed drop	x	x	x	x

Table A.2. Monitored phenophases for evergreen conifers.

USA-NPN Phenophase	Balsam fir
Breaking needle buds	x
Young needles	x
Pollen cones	x
Open pollen cones	x
Pollen release	x
Unripe seed cones	x
Ripe seed cones	x
Recent cone or seed drop	x

Table A.3. Monitored phenophases for wildflowers and forbs.

USA-NPN Phenophase	White wood aster	Garlic mustard	Common milkweed	Rough-stemmed goldenrod	Painted trillium	Bunch-berry	Marsh marigold	Purple loosestrife	Beach pea
Initial growth	x	x	x	x	x	x	x	x	x
Leaves	x	x	x	x	x	x	x	x	x
Flowers or flower buds	x	x	x	x	x	x	x	x	x
Open flowers	x	x	x	x	x	x	x	x	x
Pollen release									
Fruits	x	x	x	x	x	x	x	x	x
Ripe fruits	x	x	x	x	x	x	x	x	x
Recent fruit or seed drop	x	x	x	x	x	x	x	x	x

Table A.4. Monitored phenophases for seaweed.

USA-NPN Phenophase	Rockweed (*Ascophyllum nodosum*)
New side branches	x
Receptacles	x
Flat receptacles	x
Smooth inflated receptacles	x
Dotted inflated receptacles	x
Torn receptacles	x

Table A.5. Monitored phenophases for amphibians.

USA-NPN Phenophase	Spotted salamander	Spring peeper	Wood frog
Adults on land	x	x	x
Adults in water	x	x	x
Adults feeding	x	x	x
Vocalizing		x	x
Mating		x	x
Fresh eggs	x	x	x
Dead adults	x	x	x

Table A.6. Monitored phenophases for birds.

USA-NPN Phenophase	Ovenbird	Bobolink	Red-winged blackbird	Winter wren	White-throated sparrow	Common loon	Great black-backed gull
Active individuals	x	x	x	x	x	x	x
Feeding	x	x	x	x	x	x	x
Fruit/seed consumption	x	x	x		x		
Insect consumption	x	x	x	x	x		
Flower visitation							
Nut gathering							
Calls or song	x	x	x	x	x	x	x
Singing males	x	x	x	x	x		
Mating	x	x	x	x	x	x	x
Nest building	x	x	x	x	x	x	
Dead individuals	x	x	x	x	x	x	x
Individuals at a feeding station	x	x	x	x	x	x	

Table A.7. Monitored phenophases for Insects – Lepidoptera.

USA-NPN Phenophase	Eastern tent caterpillar	Monarch butterfly
Active adults	x	x
Flower visitation		x
Migrating adults		x
Mating	x	x
Active caterpillars	x	x
Caterpillars in tent	x	
Caterpillars feeding	x	x
Dead caterpillars	x	x
Dead adults	x	x
Individuals at a feeding station		x
Individuals at a light	x	
Individuals in a net	x	x

Appendix B. NETN Phenology Program Contact List

NPS contacts

Park/Network	Name	Position	Email
NETN	Brian Mitchell	NETN Inventory and Monitoring Program Manager	Brian_Mitchell@nps.gov
NETN	Abe Miller-Rushing	SERC/ACAD Science Coordinator	Abe_Miller-Rushing@nps.gov
NETN	Ed Sharron	NETN Science Communication Specialist	Ed_Sharron@nps.gov
NETN	Adam Kozlowski	NETN Data Manager	Adam_Kozlowski@nps.gov
NPS	Margaret Beer	NPS I&M contact for Paperwork Reduction Act compliance	Margaret_Beer@nps.gov
ACAD	Bruce Connery	Biologist	Bruce_Connery@nps.gov
ACAD	David Manski	Chief of Resource Management	David_Manski@nps.gov
ACAD	Bill Zoellick	SERC Program Development Director	bill@sercinstitute.org
ACAD	Jonathan Gormley	Volunteer Coordinator	Jonathan_Gormley@nps.gov
ACAD	Seth Benz	Director, Schoodic Bird Ecology Lab	seth@sercinstitute.org
APPA	Fred Dieffenbach	Environmental Monitoring Coordinator	Fred_Dieffenbach@nps.gov
APPA	Casey Reese	Natural Resource Specialist	Casey_Reese@nps.gov
APPA	John Odell	Resource Management Coordinator	jodell@appalachiantrail.org
BOHA/SAIR	Marc Albert	Stewardship Program Manager	Marc_Albert@nps.gov
BOHA	Mary Raczko	Volunteer Coordinator	Mary_Raczko@nps.gov
MABI	Christina Marts	Resource Manager	Christina_Marts@nps.gov
MABI	Joan Haley	Forest for Every Classroom Partner	Joan_Haley@partner.nps.gov
MABI	Melissa Fellows	Teacher	Mfellows@wuhsms.org
MABI	Jen Stainton	Teacher	jstainton@wuhsms.org
MORR	Bob Masson	Biologist	Robert_Masson@nps.gov
ROVA	Dave Hayes	Natural Resource Manager	Dave_Hayes@nps.gov
SARA	Chris Martin	Integrated Resource Program Manager	Chris_Martin@nps.gov
WEFA	Greg Waters	Horticulturist	Greg_Waters@nps.gov

Additional contacts

Name	Position	Email
Ellen Denny	USA-NPN Monitoring Design & Data Coordinator	ellen@usanpn.org
Alyssa Rosmartin	USA-NPN Assistant Director, Contact for Partner Datasets	alyssarosemartin@gmail.com
Therese Donovan	Collaborator on acoustic methods, University of Vermont	tdonovan@uvm.edu
Andrew Richardson	Collaborator on automated camera methods, Harvard University	arichardson@oeb.harvard.edu
Michael Toomey	Collaborator on automated camera methods, Harvard University	mtoomey@fas.harvard.edu
Geri Tierney	Collaborator, SUNY ESF	gtierney@esf.edu

SOP 1 – Safety

Northeast Temperate Network
Version 1.00

Overview

The Northeast Temperate Network (NETN) considers the occupational health and safety of its employees, cooperators, contractors and volunteers ("monitoring staff") to be of utmost importance, and is committed to ensuring that all personnel receive adequate training on National Park Service (NPS) safety procedures, incident reporting, and emergency response prior to field work. This SOP and supporting appendices were designed to provide a summary of safety issues that should be reviewed and understood by anyone participating in the phenology monitoring protocol, and to serve as a first reference in case of an incident. Topics covered include emergency procedures and contacts, incident reporting, field preparation, safe field procedures, vehicle safety, and workers compensation procedures. A Green-Amber-Red Risk Assessment (GAR) has been conducted for this protocol and is included as an appendix (Appendix A). Additionally, a Job Safety Analysis (JSA), which documents hazards associated with this protocol and recommends approaches to mitigate these hazards, is included as an appendix (Appendix B) to this SOP. The JSA must be read and signed by all monitoring staff who conduct field work for this protocol. Forms that go along with this SOP (Safety Acknowledgment, Safety Checklist, and Trip Plan) are provided in Appendix C. This SOP does not cover first aid.

This SOP is written to provide general guidance that should be applicable for most parks. The park Natural Resource Manager is responsible for ensuring that all volunteers or other monitoring staff have up to date emergency contact numbers, directions to medical facilities, and other park-specific safety information.

Responding to an Incident

Life-Threatening Medical Emergency

1. **Call 9-1-1 or park emergency number.** Administer first aid to the best of your knowledge, ability and training. If appropriate, transport to emergency room. Directions to the nearest hospital from each park and park-specific emergency contacts procedures will be provided to each volunteer by the park Natural Resource Manager.

2. As soon as it is practical to do so, inform the park's emergency contact (provided by the park Natural Resource Manager). The park Natural Resource Manager will inform NETN staff.

3. For NPS staff and volunteers, complete Worker's Compensation paperwork (contact the Natural Resource Manager for assistance). For contractors and cooperators, follow your organization's procedures for documenting accidents, and notify the NETN program manager with details of the incident.

Non-Emergency Incidents

1. Contact the park Natural Resource Manager immediately after incident. The park Natural Resource Manager will inform NETN staff.

2. For NPS staff and volunteers, complete Worker's Compensation paperwork (must be done within 48 hours of incident, contact the park Natural Resource Manager for assistance). For contractors and cooperators, follow your organization's procedures for documenting accidents, and notify the NETN program manager with details of the incident.

3. Seek medical attention, if needed.

NOTE: Never discard original paperwork related to workers compensation claims (including information from doctor's visits, CA-1, CA-2, CA-16 or CA-17 forms).

Field Preparation

Everyone participating in phenology monitoring is responsible for maintaining a safe work environment for themselves and others.

Job Safety

An important tool used to promote safe conduct is the Job Safety Analysis (JSA; sometimes called a Job Hazard Analysis or JHA). This approach is consistent with NPS Directors Order 50 and Reference Manual 50B for Occupational Health and Safety. The JSA process is to (1) identify hazards associated with field and laboratory settings, as appropriate, and (2) develop approaches to mitigate those hazards. All monitoring staff must review safety procedures in the Volunteer Training Manual and sign an acknowledgment that they have read the JSA in Appendix B.

First Aid Kits and Training

NETN strongly encourages all monitoring staff to carry a backpacking first aid kit with them in the field. An inventory of first aid kits should be performed prior to each field season to ensure that all medical supplies are in sufficient quantity and haven't expired. Each first aid kit should have an inventory list of the supplies it should contain. Items in first aid kits that are used should be promptly replaced. If you do not have access to a first aid kit and want to carry one, let the park Natural Resource Manager know and NETN will purchase one that can be borrowed from the park.

NETN also strongly encourages all monitoring staff to obtain basic first aid and CPR training, particularly if they have not been certified in the past 5 years.

Teamwork

NETN recommends that people work in teams of two or more for monitoring at sites which are off-trail or at remote or hard to access sites. Working with another person makes it more likely that someone will be able to obtain help in the event of an accident, and working with someone else usually makes field work more enjoyable. If you are unable to find someone to work with you and you would like to work with someone else, please notify the park Natural Resource

Manager and he or she will try to find a field partner for you. For monitoring at designated, accessible sites that are on or near trails, monitoring may be done alone or with a partner.

Daily Communication and Planning

Monitoring staff are expected to carry a reliable communication device. In most NETN parks, a personal cell phone can be used. At ACAD, cell phones are not reliable and NETN has purchased a Personal Locator Beacon (PLB) and SPOT GPS Messenger that can be checked out by volunteers. The SPOT GPS Messenger can be used for checking in at the end of the field day (as well as sending an emergency signal if needed), while the PLB is a more reliable emergency signaling device. Monitoring staff must fully understand how to operate all communication devices before heading into the field. All modes of communication must be fully charged and tested at the beginning of each day. APPA also has poor cell phone coverage, but it is not logistically possible for NETN to provide emergency communication devices for this park.

Monitoring staff must notify the park Natural Resource Manager (or a designated individual; RM/DI) with an expected schedule for field work including sites or routes to be surveyed prior to commencement of site visits. Phenology monitoring occurs frequently (daily to weekly during the growing season) and may be weather dependent, so the expected schedule need not specify exact dates. For example, a seasonal phenology monitoring plan might specify that a volunteer will visit a specific, designated site (e.g., ACAD site 3191) every other day from April to June, and then weekly in July and August, and that visits will usually occur in the early morning. On each monitoring day, monitoring staff must know where they will be monitoring and how they will get there before going into the field.

At off-trail or remote sites, the RM/DI must be contacted the day before field work will occur and provided with the monitoring staff name, cell phone number, vehicle license plate number, expected parking location(s), name of the monitoring route, and estimated time of arrival and departure from the park. Monitoring staff must also establish a check-in time for completion of field work. If monitoring staff do not check in on or before the planned check-in time for completion of field work, the RM/DI will immediately try to reach them by all available methods. If the monitoring staff have not been reached within 30 minutes, the RM/DI will notify emergency services and initiate a search.

At ACAD, when the NETN PLB and SPOT GPS Messenger are being borrowed by the monitoring staff the trip information must also be provided to the NETN staff members responsible for tracking messages from the devices. NETN must also be provided with the RM/DI name, phone number, and e-mail, and the RM/DI must be provided with contact information for NETN staff.

If the survey is cancelled or if the plan changes while in the field, staff must notify the RM/DI immediately. At the end of the day, staff must notify the RM/DI that they have returned from the field. At ACAD, the SPOT Messenger can be used to notify NETN that more time is needed in the field or that field work is completed; NETN staff will relay this message to the RM/DI. If NETN staff are not contacted, they will assume that the monitoring staff checked in directly with the RM/DI.

Monitoring staff are responsible for being aware of the time and ensuring that end of day check-ins occur on schedule; the RM/DI will call emergency services if the monitoring staff misses their check in and cannot be located within 30 minutes of the check-in time.

At designated, accessible sites on or near a trial, it is not necessary to contact the RM/DI on each monitoring day for check-in/check-out. However, all monitoring staff must notify a trusted person (spouse, friend, co-worker, etc.) of their whereabouts during monitoring activities, and that person must be given contact information for the RM/DI in case of an emergency.

Personal Gear

Monitoring staff are responsible for ensuring they are wearing field appropriate clothing and footwear such as long pants, a hat and hiking boots. Depending on the weather, rain gear or warm clothing should be taken into the field and it is recommended that an extra set of clothing be kept in the vehicle. Monitoring staff should take care to avoid over exposure to the sun by wearing sunscreen and/or protective clothing. Monitoring staff should always carry ample water (2-3 liters for travel to remote or hard to access sites) and food when working in the field. Dehydration is a serious condition that can lead to more serious conditions if untreated, and should be avoided. It is important to drink liquid frequently to maintain hydration on a warm day, even if you don't feel thirsty.

Field Safety

Slip, Trip, Fall Prevention

Uneven terrain, slippery rocks, dense brush, and fatigue are all hazards that could result in a slip, trip, or fall. The following guidelines should be obeyed by monitoring staff to avoid injury from slips, trips, or falls:

- Always wear appropriate footwear such as sturdy hiking boots.
- Pay attention to where you are going, and remain alert of potential hazards.
- Walk at an appropriate pace and adjust pace for changes in terrain (e.g., slow down and take smaller steps on slippery surfaces).
- When hiking long distances, take breaks to avoid fatigue.
- When navigating to a location off trail, choose the safest route (this may not be the shortest route). Avoid river crossings, excessively steep terrain and sudden drop-offs. Always be careful when navigating over piles of scree, and alert others of falling rocks.

Proper use of Backpacks

Monitoring staff may carry a day pack (with personal gear, water, and clipboard) weighing more than 20 pounds, and it is important for everyone to understand appropriate ways to pack, lift and carry a backpack to avoid back, neck and shoulder injuries. Monitoring staff should follow these guidelines, especially if carrying more than 30 pounds:

- Use a sturdy field pack with padded and adjustable hip and shoulder straps.
- Pack heavy items in the center of the pack and close to your back.
- Make sure weight is evenly distributed from side to side.
- Once equipment is packed, tighten the compression straps to minimize movement inside the pack during travel.

- When picking up a heavy pack, use your legs to do the lifting, and use slow, smooth movements. Keep your back straight, and keep the pack close to your body. Do not twist or bend at the waist, and do not swing the pack quickly over one shoulder.
- Always carry a pack with both shoulder straps and with the hip belt and chest straps secured.
- The pack should be positioned near the center of the back, and most of the weight should rest on your hips.
- Keep your pack organized, and only carry the necessary equipment, food and water to reduce weight.

Weather

Weather conditions in the eastern U.S. can be hazardous and can change quickly. Monitoring staff are responsible for planning their day according to the local weather forecast and for being aware of their surroundings and changing conditions.

Thunderstorms

Storms that produce strong winds and lightning are dangerous and should be avoided in the field. If caught in a lightning storm, seek shelter in a building or car as soon as possible. If no shelter is available, spread out and move to an open space. Squat low to the ground on the balls of your feet with your hands on your knees (do NOT lie flat on the ground). Avoid high elevations, conductive materials, and tall structures such as trees or telephone poles. If you are in the open and feel your hair stand on end (indicating lightning is about to strike), immediately make yourself the smallest target possible and minimize contact with the ground.

NOTE: A person struck by lightning can often be revived by prompt administration of CPR and oxygen.

Excessive Heat and Sun

Over exposure to heat and sun can cause dehydration, heat exhaustion, or heat stroke. All are serious conditions that can be life threatening, and should be avoided. When working in hot weather, be sure to drink plenty of water and eat foods that can replace electrolytes. Wear loose and light colored clothing, including a hat to block the sun's rays. It may help to shift the field schedule to avoid working outside during the hottest part of the day.

WARNING: Signs of heat stroke include hot, red or spotted (usually dry) skin, and the sufferer may be mentally confused, delirious, having convulsions, or unconscious. If heat stroke is suspected, seek immediate medical attention!

Poor Air Quality

Summer ozone and particulate matter levels occasionally exceed federal health standards. Young children, seniors, and those suffering from asthma, chronic bronchitis, and chronic obstructive pulmonary disease or heart problems are especially sensitive to poor air quality and should minimize outdoor activity when poor air quality warnings are posted. The risks of occasional exposure to ozone and fine particulate matter are minimal for healthy individuals.

When poor air quality warnings occur, it is advisable for monitoring staff to avoid overly strenuous activity during the hottest part of the day (pollution levels tend to be lowest early in the morning), and to stick to lower elevations under a forest canopy.

To check local air quality forecasts, or learn more about health risks of air pollution, visit the AIRNow intergovernmental agency website: http://www.airnow.gov/.

Deer ticks and Lyme Disease

Several species of ticks are commonly encountered in eastern U.S. parks while working in the field (Figure S1.1). This includes the deer tick (*Ixodes scapularis*), which is a known vector of Lyme disease and Ehrlichiosis. Infected deer ticks are abundant from New Jersey to southern New Hampshire and common elsewhere in New England, and Lyme disease is a serious Safety concern in all NETN parks. Monitoring staff must take the precautions outlined below to help minimize the chances of having an embedded tick that could lead to illness:

- Clothes treated with tick and insect repellents have been found to be fairly effective tick repellant. Monitoring staff are strongly encouraged to treat their clothing with permethrin prior to conducting monitoring. Monitoring staff should carefully follow the application instructions on the spray bottles to ensure their safety. Permethrin will remain active for several weeks and through several washings.
- Monitoring staff should take additional precautions to protect themselves from ticks, including tucking pants in socks and tucking in shirts. Long sleeves and gaiters have been found to help.
- Check clothes and skin for ticks at the end of every field day. Ticks typically need to be embedded for at least 24 hours for disease transmission to occur; therefore, the earlier ticks are found and removed, the lower your chances are of acquiring a tick-borne illness.
- If you find a tick that is already embedded, use fine-tipped tweezers to firmly grasp the tick close to your skin. Slowly and steadily pull the tick's body away from your skin. Be careful not to crush the tick's body to minimize the chances of it regurgitating fluids into the wound. Clean the bite area once the tick is removed with soap and water.
- If you receive a deer tick bite, notify the park Natural Resource manager, who will help you start a worker's compensation CA-1 claim to get a CA-16. If you start to notice symptoms of a tick borne disease, use the CA-16 to get medical treatment.
- Keep an eye out for any early symptoms of tick borne diseases. Symptoms may include a bull's eye rash around the tick bite (doesn't always occur), tingling or numbness in extremities, a spotted rash on extremities, bad headaches, high fever, joint aches, stiff neck, fatigue, or swollen glands. If you develop a combination of these symptoms soon after a tick bite, seek medical attention.

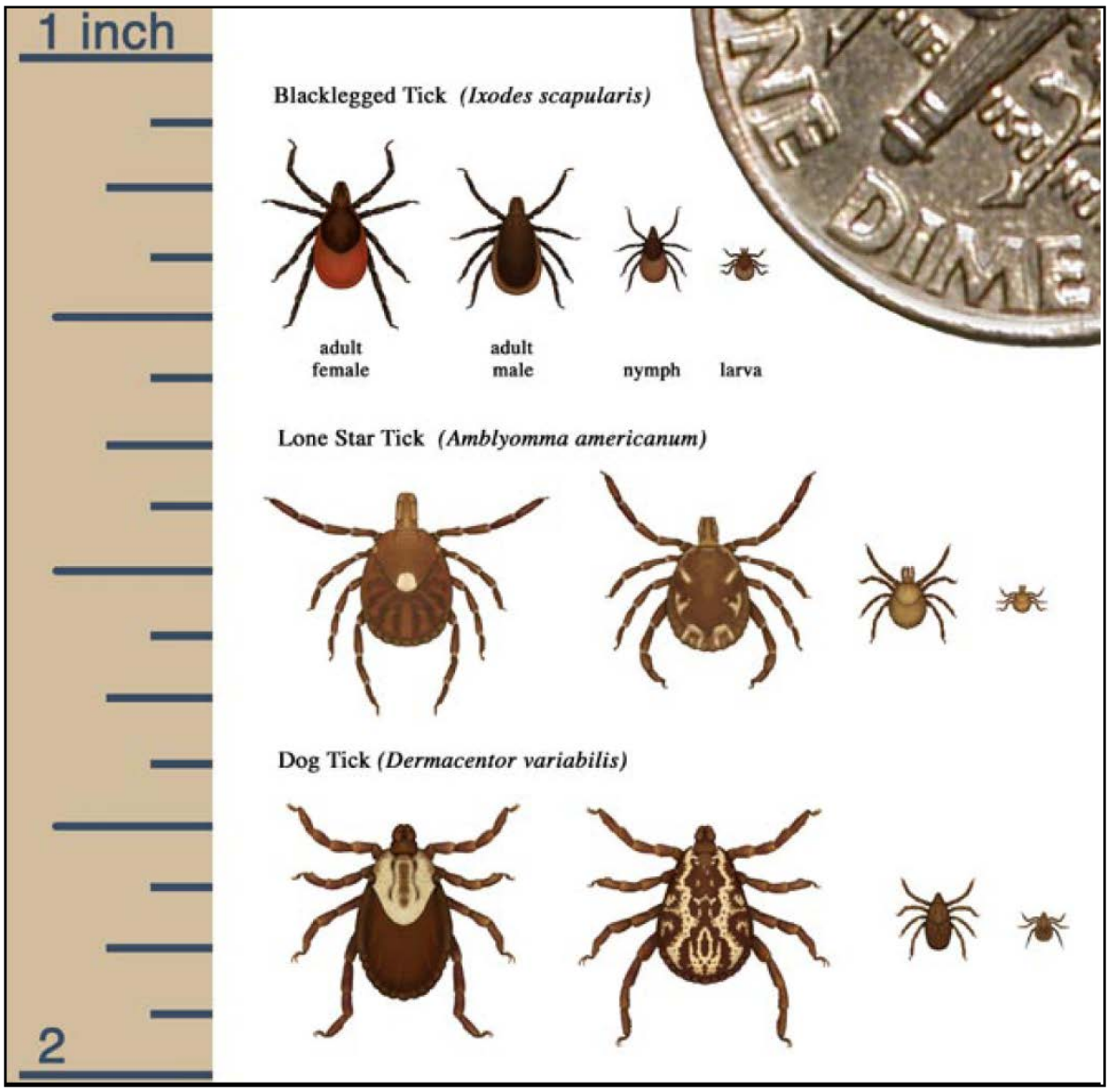


Figure S1.1. Tick species found in the eastern US.

Considerations for using repellents containing DEET:

- DEET products have been widely used for many years; these products have occasionally been associated with some adverse reactions. Frequently, reported reactions are about skin or eye irritation. There have been reports of central nervous system problems.
- By using products with lower concentrations of DEET and by applying as little of the product as needed for your outdoor work, you can reduce your expose to DEET.
- Products with about 20 - 30% DEET are considered effective for most insects, but do not seem to be effective against the black-legged or deer tick (*Ixodes scapularis*)
- Generally, products with about 20 - 30% DEET are considered safe for adults (except for those with allergies to DEET products) when applied as directed.

Considerations for using repellents containing permethrin:

- Products containing permethrin are for use on **clothing only – not for use on skin**.
- Permethrin kills ticks that come in contact with treated clothing and one application lasts two weeks or more. Do not treat the clothing more than once every two weeks.
- Carefully read and follow manufacturer's instructions for application, and refer to the MSDS sheet if you have questions.
- Do not apply while clothing is being worn.
- Apply to clothing item in a well-ventilated outdoor area, protected from wind.
- Lightly moisten the fabric with permethrin – do not saturate the fabric.
- Allow clothing item to dry outdoors for at least two hours before wearing (4 hours in humid conditions).
- Keep treated clothes in a separate bag for storage and transport.
- Launder treated clothing, separately from other clothing.

More information on permethrin:
http://www.epa.gov/oppsrrd1/REDs/factsheets/permethrin_fs.htm
http://drugsafetysite.com/permethrin/

Prophylactic (preventative) use of antibiotics:
Antibiotics are sometimes used to prevent Lyme disease transmission from the deer tick. Antibiotics may be prescribed following a deer tick bite if the tick was attached for 24 or more hours, AND the bite occurred in an area where Lyme disease is common. Other tick borne diseases are usually treated using antibiotics only after symptoms become obvious.

A few things to keep in mind about antibiotic therapy:
According to the US Public Health Service, Centers for Disease Control:

- Every time a person takes antibiotics, sensitive bacteria are killed, but resistant germs may be left to grow and multiply. Repeated and improper uses of antibiotics are primary causes of the increase in drug-resistant bacteria.
- Misuse of antibiotics jeopardizes the usefulness of essential drugs. Decreasing inappropriate antibiotic use is the best way to control resistance.
- Antibiotic resistance can cause significant danger and suffering for people who have common infections that once were easily treatable with antibiotics. When antibiotics fail to work, the consequences are longer-lasting illnesses; more doctor visits or extended hospital stays; and the need for more expensive and toxic medications.

More information on Lyme Disease and Ticks:
Center for Disease Control:
http://www.cdc.gov/lyme/
(also a free webinar on tickborne diseases)

American Lyme Disease Foundation:
http://www.aldf.com/

Tick Management Handbook:
http://www.ct.gov/caes/lib/caes/documents/publications/bulletins/b1010.pdf

Poisonous Plants and Animals

Both for safety and protection of park resources, it is never advisable for monitoring staff to eat wild plants while working in a National Park, regardless of their confidence in plant identification. Keep a safe distance from wildlife.

Poison Ivy

Poison ivy (*Toxicodendron* spp.) is present in most NETN parks, and can be very abundant in localized areas. When working in areas with poison ivy, it is advisable that monitoring staff learn to recognize this plant and take precautions to avoid skin contact with any part of it. Using a pre-exposure cream and wearing long sleeves and long pants can help reduce the amount of skin contact with the plant. If needed, use poison ivy wipes after contact. Monitoring staff should be careful not to rub their faces when working around poison ivy. After working in an area with abundant poison ivy, monitoring staff should gently wash exposed skin in cool water with poison ivy soap, and should change into fresh field clothes. At the end of a field day, monitoring staff should also wash potentially contaminated equipment (e.g., backpack). If a severe allergic reaction occurs, the affected individual should seek medical attention, notify the park Natural Resource Manager as soon as possible, and file a workers compensation claim.

Venomous Snakes

The following species of venomous snakes may occur in some NETN parks: copperhead (*Agkistrodon contortrix*), cottonmouth (*Agkistrodon piscivorus*), and timber rattlesnake (*Crotalus horridus*). The best course of action is to avoid all snakes by keeping them at a safe distance. When in poisonous snake country, pay attention to where you put your hands and feet, and be aware around rock piles and bedrock outcrops. Note that many snake bites are purely defensive, and contain no venom. Bites from immature snakes are much more likely to contain a more dangerous amount of venom than bites from adult snakes. Should you receive a snake bite from a potentially poisonous snake, follow the procedure below:

- Treat all bites as if envenomation has occurred.
    - Time is of the essence
    - If working in a team, assign one person to use a cell phone to call for assistance. Identify the call as a snakebite incident, and identify the victim's location and the closest possible point of access for responders.
    - Quickly remove rings, watches, shoes etc., before swelling begins.
    - Immobilize the bitten limb firmly with a splinted elastic (Ace) bandage and get the victim out of the woods and to a hospital as quickly as possible.
    - **Do not** use thin circulation restrictive cords, pack with ice for long periods (more than five minutes) or attempt to cut open or otherwise enlarge the fang punctures.

- Reassure the victim that they will be OK and otherwise attempt to maintain the calm both for the victim and for all others involved.
    - In a crew situation, begin leading the victim slowly out of the woods as soon as the bitten limb has been immobilized. **Move as slow as necessary to maintain a normal heart rate for the victim.** Waiting for assistance will only prolong the process of getting proper medical treatment.

    - In a solitary situation, establish radio or telephone contact and relay the necessary information as you walk slowly out of the woods. Focus on remaining calm and maintaining a normal heart rate.

- It is better to spend your available time getting to proper medical treatment facilities than it is to fumble with field therapy and wait for assistance to reach you.

The range of the copperhead covers the following NETN parks: Appalachian NST (APPA), Morristown NHP (MORR), Roosevelt Vanderbilt NHS (ROVA), Saratoga NHP (SARA) and Weir Farm NHS (WEFA). The likelihood of encountering a copperhead is low in NETN parks, although higher along the southern portions of APPA. Copperhead bites are not typically considered life threatening, and in most cases antivenin is not administered.

The range of the cottonmouth covers the southern portions of APPA. Cottonmouth bites that are defensive typically do not contain venom. However, cottonmouth snakes are capable of delivering a lethal dose.

The range of the timber rattlesnake covers all NETN parks except ACAD. This species is listed by NatureServe as "critically imperiled" (S1: New Hampshire, Vermont, Massachusetts, and Connecticut) or "vulnerable" (S3: New York, Pennsylvania) throughout NETN, and the likelihood of encountering a timber rattlesnake in NETN parks is very low (although higher along the southern portions of APPA). Adult timber rattlesnakes are capable of delivering a lethal dose of venom.

Bees, Wasps, and Yellow Jackets

If any monitoring staff are allergic to bee stings, they should alert their colleagues and make sure to carry appropriate medications. If they carry an epinephrine injector and are working in a team, they should make sure their colleague knows where it is carried. Be alert to potential hive and nest locations while hiking to plots and working on plots. Look for insects travelling in and out of one location (e.g., brush, ground holes, and hollow logs). If someone is stung, Benadryl and a cold compress may bring relief. If stinger is left behind, scrape it off of skin. Do not use tweezers as this squeezes the venom sack, worsening the injury. If the victim develops hives, asthmatic breathing, tissue swelling or a drop in blood pressure, seek medical help immediately.

Black Bears

Black bears range throughout the Northeast and along the entire Appalachian NST, but an encounter with a bear in the field is not likely since bears generally avoid people. Nevertheless, be alert for bears near dawn or dusk, and be especially aware of mother bears with cubs. Never approach cubs or come between a mother bear and her cubs. If a bear is encountered, face the animal and continually make noise – do not freeze or remain silent. Appear larger by standing tall, waving arms or jacket over your head, and slowly back away. Never run from a black bear; if charged or attacked, throw objects and shout loudly, and fight back aggressively.

Vehicle Safety

Responsibilities of Vehicle Operators

Virtually all monitoring staff for the phenology protocol will be using their personal vehicles to get to and from their monitoring sites. Monitoring staff are responsible for inspecting their vehicles before every use to ensure the vehicles are in safe working condition. This includes visually checking tire pressure, adjusting mirrors, and making sure equipment is secure, as well as taking care of preventative maintenance in a timely manner. It is strongly recommended that monitoring staff obey the following rules (these rules are mandatory in government vehicles):

- Wear a seat belt.
- Do not use cell phones (both talking and texting) while driving.
- Adhere to all federal and state vehicle regulations, including all posted speed limits.

Procedures for reporting a motor vehicle accident

In the event of an automobile accident, volunteers and NPS staff should follow NPS accident reporting procedures. Cooperators or contractors would need to follow their organization's procedures. The NPS procedures are as follows:

1. Stop immediately and turn on emergency flashers.

2. Take steps to prevent another accident at the scene.

3. Call 911 or ambulance if necessary.

4. Notify police, NPS law enforcement (if at a park with law enforcement – ACAD, MIMA, MORR, and SARA) and the park Natural Resource Manager. The park Natural Resource Manager will notify NETN staff.

5. In the event of death, actual or potential serious injury, or significant property damage (damage greater than $2,500), the staff involved must convey this information as soon as is practical to NETN staff, so that the NPS Regional Tort Claims Officer (TCO), Dave Schuller (215-597-5368), can be notified.

6. In reporting an accident, monitoring staff should state the facts to the best of his/her knowledge. **Conclusions as to fault or responsibility should not be stated.** Monitoring staff should report the accident only to authorized representatives of the Government, their insurance company, and police officers investigating the accident. Monitoring staff shall also file any report required by law.

7. Get name and address of witness (preferably two witnesses). Ask witness to complete Standard Form (SF) 94, Statement of Witness, if the form is available.

8. State/provide your name, address, place of employment (or park where volunteering), name of your supervisor (park Natural Resource Manager if a volunteer), and upon request show your driver's license and vehicle registration information.

9. Complete Standard Form (SF) 91, Motor Vehicle Accident Report as soon as practical. If conditions prevent this, make notes of the following:

    a. Registration information for other vehicle(s) (owner's name, owner's address, tag number, VIN, and vehicle description)

    b. Information on other drivers (name, address, operator's permit, and expiration date)

    c. Name and address of each person involved and extent of injury, in any.

    d. Name and address of company insuring other vehicle(s) and insurance policy number

    e. General information such as location, time, measurements, weather, damage, etc.

10. Encourage police to provide a Police Report and, if available, submit a copy with SF 91.

11. If you have a camera, take pictures of the accident scene and any damage to the vehicles involved. Submit along with SF 91.

12. If vehicle is unsafe to operate, arrange for towing services (if a government vehicle, pay using the vehicle gas card).

13. Submit all reports and data to the park Natural Resource Manager within one working day.

14. If a federal employee or volunteer is injured, the workers compensation process needs to be initiated <u>within 48 hours of incident.</u> The park Natural Resource Manager will assist with this process. It is important for injured monitoring staff to receive prompt medical treatment. <u>Make sure the employee sees a doctor, not a nurse, nurse practitioner, or physician's assistant.</u>

15. The park Natural Resource Manager will submit copies of all reports and data to the NPS regional TORT Claims Officer (TCO) [Dave Schuller 215-597-5368] as soon as possible <u>but no later than 10 calendar days after the accident</u>.

Accident/collision reports should be filed for:

1. All motor vehicle accidents involving federally owned or leased vehicles and employee-owned or rented vehicles while being used on official business, regardless of the amount of damage.

2. All public/visitor accidents will be reported on a SF-91 when a government-owned vehicle is involved, government property is damaged, fatality occurs, medical treatment is required and/or a reasonable possibility of a tort claim is expected.

3. Thefts and Vandalism should be reported to Park Law Enforcement Officials rather than reported on SF-91.

4. Reporting Multiple Vehicle Accidents – when a privately owned vehicle damages Government property, two reports (SF-91) are required: one report for the Government property and one for the private operator.

Appendix S1.A. Green-Amber-Red Risk Assessment

This appendix describes application of the GREEN-AMBER-RED (GAR) Risk Assessment Model as outlined in the NPS Operational Leadership Student Manual (Version 2; July 2011) to the NETN Phenology Monitoring Protocol. This GAR was written by the NETN Program Manager (Brian Mitchell) on 26 February 2012, revised based on internal review on 11 November 2012, and approved by the NPS Northeast Region I&M Program Manager (John Karish) on 9 May 2013.

The GAR model allows for a general assessment of a task or operation and generates communication concerning the risks of an activity (in this case, conducting the field-based activities of the NETN Phenology Monitoring Protocol). The most important part of the process is the team discussions leading to an understanding of the risks and how they will be managed.

The GAR is a seven step process. Each step is defined and explained in the context of the NETN Phenology Monitoring Protocol below.

Step 1: Define the Mission or Task

The NETN Phenology Monitoring Protocol includes a field-based monitoring activity: surveying the phenology of plants and animals at different sites or along routes in different habitats. Monitoring staff are usually volunteers who work independently and are coordinated by the park Natural Resource Program Manager). Staff are encouraged to work in pairs if visiting remote or hard to access locations, and NPS has agreed to help find partners for monitoring volunteers when the volunteers request a partner. The activity is sometimes conducted away from roads and trails. Potential safety hazards (along with mitigation measures) have been identified in a Job Safety Analysis (JSA; Appendix B). Of specific concern is that monitoring staff may be working in fairly remote areas with limited communication options in the event of an emergency (especially at ACAD and APPA). A serious injury due to a trip and/or fall while traversing uneven or steep terrain is possible and is the most significant risk encountered when conducting this activity.

Step 2: Define the Threats

The threats/hazards for this activity along with mitigation measures are described in the associated JSA (Appendix B).

Step 3: Assess Risk and Assign a Numerical Value

The numerical ranks (Table S1.1) were assigned by Brian Mitchell, the NETN Program Manager and the NPS project leader for the NETN Phenology Monitoring Protocol. NPS staff reviewed the ratings and analysis and their suggestions were incorporated. It should be noted that at the time numerical values were assigned (February 26, 2012) the protocol had been in development for 4 years and similar protocols had been in place for up to 6 years, and considerable time and effort had already gone into evaluating and mitigating risks.

The GAR process is described in NPS Operational Leadership Student Manual (Version 2; July 2011).The activity risk can be visualized using the colors of a traffic light. If the total risk value falls in the GREEN ZONE (1-35), risk is rated as low. If the total risk value falls in the AMBER ZONE (36-60), risk is moderate and you should consider adopting procedures to minimize the

Appendix S1.A. Green-Amber-Red Risk Assessment (continued).

risk. If the total value falls in the RED ZONE (61-80), you should implement measures to reduce the risk prior to starting the event or evolution.

The ability to assign numerical values or "color codes" to hazards using the GAR Model is not the most important part of risk assessment. What is critical to this step is team discussions leading to an understanding of the risks and how they will be managed.

Table S1.1. NETN Phenology Monitoring Protocol assigned risk codes of 0 (For No Risk) through 10 (For Maximum Risk) to each of the eight Green-Amber-Red Risk Assessment elements.

Element	Rating
Supervision	4
Planning	3
Communication	3
Contingency Resources	6
Team Selection	6
Team Fitness	3
Environment	3
Event/Evolution Complexity	5
Total Risk Score	33

Step 4: Identify Risk Control Options

Supervision

The NETN Phenology Protocol clearly identifies personnel, roles and responsibilities, and a chain of command. At each park, the park Natural Resource Manager coordinates the monitoring effort. This person is the supervisor and is available to provide training and answer questions from monitoring staff. The staff are encouraged to work with a partner in the field but may opt to work alone. Monitoring staff visiting remote or hard to access locations are required to follow check-in and check-out procedures with the park Natural Resource Manager. A score of 4 was assigned because of the loose supervision and the likelihood that many monitoring staff will work alone.

Planning

The NETN Phenology Monitoring Protocol includes numerous SOPs that explain training, personal safety, emergency communication (equipment and contacts), and appropriate field activities. Monitoring staff are asked to review the volunteer manual, which summarizes relevant field procedures and provides a summary of the safety SOP, and they must sign an acknowledgement that they have reviewed the JSA. Monitoring staff are highly recommended to have first aid and CPR training. Due to this advance planning, written documentation, and training procedures, a low score (3) was assigned.

Communication

Routine and emergency communication procedures are explained in the relevant SOPs, and monitoring staff are provided with contact information specific to their assigned park. The procedures include coordination with park natural resource managers and other designated park staff. It also includes a daily check-out/check-in procedure for monitoring staff visiting remote or hard to access locations to ensure that a responsible party knows if someone has not returned from the field activity in a timely manner. Due to this advance planning, written documentation, and training procedures, a low score (3) was assigned.

Appendix S1.A. Green-Amber-Red Risk Assessment (continued).

Contingency Resources

Contingency resources include communication equipment and procedures that explicitly involve park rangers, park dispatch, and 9-1-1. Monitoring staff are required to carry a cell phone, but coverage is not complete in many parks. At one park with poor cell coverage (ACAD), monitoring staff can check out a Personal Locator Beacon and SPOT GPS Messenger to facilitate check-ins and emergency response. At the other park with poor cell coverage (APPA), logistics prevent providing similar equipment. In the worst case scenario, an incident involving a solo individual in an area with no cell phone coverage could result in a long delay before emergency services are alerted. However, monitors use marked sites and routes that are generally on or near established trails. They also set up explicit check-in times for visits to remote or hard to access locations, so if a search is initiated after a missed check-in the individual should be located within a few hours of starting a search. A score of 6 was assigned for this worst-case scenario.

Team Selection

The monitoring protocol identifies the essential skills and abilities required to execute this protocol in a competent manner, but one of the features of this protocol is that significant experience is not required. Monitoring staff may have limited experience with research and field work, and many of them are retirees. There is also variation in their orienteering and hiking experience. Monitoring staff are strongly encouraged to obtain basic first aid and CPR certification, and to work with a partner if they are at all concerned about field conditions. A score of 6 was assigned because some monitoring staff may have limited experience with off-trail hiking and navigating.

Team Fitness

The nature of the Phenology Monitoring Protocol should ensure an overall high level of team fitness. The monitoring itself is not difficult or time consuming, although significant travel/hiking time may be needed for some parks and sites (especially ACAD and APPA). A score of 3 was assigned because the monitoring does not take long, even though hiking to the sites or routes can be strenuous. Monitoring staff must be diligent about adequate rest and nourishment to ensure that fatigue does not become a factor.

Environment

Environment was assigned a low score (3) because the work may involve some travel off of established trails, on uneven terrain. Activities may occur during a variety of weather conditions, although staff are told not to monitor if the weather forecast calls for severe weather.

Incident Complexity

Incident complexity was assigned a medium score (5) because daily field conditions change due to weather. Individual monitoring staff must use judgment and experience to respond appropriately.

Step 5: Evaluate Risk vs. Gain

The scores for this assessment fall near the top of the "green" zone, indicating a low risk activity. While it is theoretically possible to make changes to reduce risk even further, doing so will likely cause volunteers to leave the program due to intrusive requirements. The NETN Program Manager feels that the current procedures provide a good balance that encourages monitoring

Appendix S1.A. Green-Amber-Red Risk Assessment (continued).

staff to be safe without being overly protective. NETN feels that this monitoring activity, if carried out in accordance with all SOPs, has an acceptable level of risk.

Step 6: Execute Decision

The decision made by the NETN Program Manager is to conduct the activity in accordance with NETN Phenology Monitoring Protocol Standard Operating Procedures (SOPs).

Step 7: Supervise – Watch for Change

The NETN Program Manager continually solicits feedback from the contractor and NPS staff on safe execution of the protocol including risk control options not considered thus far.

Appendix S1.B. Job Safety Analysis

JOB SAFETY ANALYSIS: Phenology Monitoring Field Work and Travel to, from, and within Parks	**JOB TITLE:** Phenology Monitor **DEPARTMENT:** Northeast Temperate Network **ANALYSIS BY:** Brian R. Mitchell, NETN Program Manager	☒ **NEW** ☐ **REVISED** ☐ **REVIEWED** John Karish, NER I&M Program Manager
Required and/or Recommended Personal Protective Equipment: Required: At least one method of communication (i.e., cell phone in most parks; Personal Locator Beacon and SPOT GPS Messenger at ACAD), driver's license. Recommended as appropriate: first aid kit, rain gear, condition-appropriate footwear and clothing, sufficient food and water.		

Tasks	Potential Hazards	Recommended Action or Procedure
Planning and Communication	Not being prepared and following plan/itinerary. Communication breakdowns.	• Plan ahead. Know where you will be going, the route to be surveyed, and any particular hazards associated with the monitoring route. Check the weather forecast and plan accordingly. • For visits to remote or hard to access locations, check in with park resource manager or designated individual (RM/DI) prior to field work with a trip plan, and after field work to confirm the work is safely completed. Contact the RM/DI with any changes, including cancellation of field work. If return will be delayed, contact RM/DI before agreed-upon check-in time to establish a new check-in time. • Always carry at least one method of communication, and verify that it has a full charge before starting field work.
Emergency Preparedness	Not knowing emergency procedures. Not having emergency supplies.	• Know who to contact and how to reach them in the event of a life-threatening or non-life-threatening emergency. • Have current CPR and first aid certification. • Carry a well-maintained first aid kit.

Appendix S1.B. Job Safety Analysis (continued).

Tasks	**Potential Hazards**	**Recommended Action or Procedure**
General foot travel	Falling or tripping due to wet areas, poor footing, uneven terrain, loose/rolling rocks and heavy pack.	• Use caution at all times. Walk carefully, watching footing. • Wear appropriate boots for conditions. Stay aware of your feet. Address blisters and hot spots promptly. • Avoid carrying excessive weight loads or unbalanced loads. • When walking on a steep slope, lean upslope. [illegible]s are alive and can [illegible]e relying on them. • Use extreme caution traversing wet rocks, streams, steep slopes or blowdown areas.
Working outdoors during storms	Being struck by falling trees or branches; being struck by lightning	• Listen to the weather forecast each morning (park radio and/or internet). • Plan or adjust field work to avoid being out in thunderstorms. • Postpone work if safety will be compromised by storm conditions. If you see or hear a thunderstorm coming, retreat from high ground and exposed areas. Go inside a sturdy building or vehicle, if possible. • If you can't get inside and if you feel your hair stand on end, lightning is about to strike. • Make yourself the smallest target possible and minimize contact with the ground. • Crouch down on your pack on the balls of your feet and keep your feet close together. Place your hands on your knees and lower your head. • During a thunderstorm, members of the crew should stay separated by at least ten feet.
Poisonous plants, especially poison ivy	Contamination/toxicity from contact with poisonous plants	• Learn to identify poison ivy in its many growth forms. • Wear long sleeves and pants. • Be aware of poison ivy and avoid coming in direct contact with it. • Thoroughly wash hands, equipment, and clothes with Tecnu or similar specialized soap if you come into contact with poison ivy.
Working in bear territory	Black bear encounter	• Be especially alert near dawn or dusk. • Be especially aware of mother bears with cubs. Never approach cubs or come between a mother bear and her cubs. • Face the animal, continually make noise – do not freeze or remain silent. • Appear larger by standing tall, waving arms or jacket over your head. • Slowly back away – do not approach a bear. • Never run from a bear. • Throw things and shout loudly. • Fight back aggressively.

Appendix S1.B. Job Safety Analysis (continued).

Tasks	**Potential Hazards**	**Recommended Action or Procedure**
Bee, wasp, or yellow-jacket stings	Multiple stings from disturbing or stepping into nest areas	• Be alert to hives in brush, ground holes, or hollow logs. Watch for insects traveling in and out of one location. • If you are allergic to bee stings, tell your partner (if working in a pair). Make sure you carry emergency medication with you at all times and that your partner (if applicable) knows where you keep it. • Wear long sleeve shirts and trousers, tuck in shirt. Bright colors and metal objects may attract bees or wasps. • If you are stung, a cold compress may bring relief. • If stinger is left behind, scrape it off of skin. Do not use tweezers as this squeezes the venom sack, worsening the injury. • If the victim develops hives, asthmatic breathing, tissue swelling or a drop in blood pressure, seek medical help immediately.
Bites from mosquitoes, black flies, and other insects	Itchy reactions to multiple bites	• Wear long sleeves and pants. • Avoid sitting on the ground or on logs, especially in dry sunny grassy areas. • Use insect repellants. Do not apply Permethrin, Permanone, or greater than 30% DEET directly to skin, only to clothing. • Carry after-bite medication to reduce skin irritation.
Ticks	Contracting diseases transmitted from ticks	• Use tick avoidance precautions, including pre-treating clothing with permethrin, tucking pants into socks and shirt into pants when hiking. • Wear clothes (including pants and long-sleeved shirts) that are light colored and check for ticks on clothing after traveling through vegetation. • Conduct a thorough tick check every evening after completing field work. • Know how to identify tick life forms, and the signs & symptoms of tick-borne diseases.

Appendix S1.B. Job Safety Analysis (continued).

Tasks	**Potential Hazards**	**Recommended Action or Procedure**
Venomous snakes	Being bitten by a venomous snake	• Venomous snakes are rare in NETN parks, although more common along southern portions of the Appalachian Trail. • Be alert for snakes in thick vegetation and rocky habitats. • Look **before** putting hands or feet in places out of immediate view. • Treat all bites as if envenomation has occurred. • Immobilize the bitten area and keep it lower than the heart. • Apply a bandage, wrapped two to four inches above the bite, to help slow the venom. This should **not** cut off the flow of blood from a vein or artery - the band should be loose enough to slip a finger under it. • Remove rings, watches, shoes, etc. before swelling begins in earnest. • Seek medical attention immediately and/or call for help. Remain calm. • Rattlesnake bites are more likely to be life-threatening.
Walking through thick vegetation	Cut, scratched, or bruised by vegetation; eye or ear injuries	• Shield your eyes and face with your hands, glasses, or hat when moving through tall thick brush. Keep your head and eyes pointed somewhat downward so your head hits obstacles before your eyes. • Wear pants and long-sleeved shirts to protect bare skin. • Look before you grab vegetation to avoid grasping thorny stems. • Do not follow closely behind other people to avoid having branches snap back and hit you.
Crossing streams	Injuries from falling and/or drowning	• Do not cross streams that are flowing quickly and higher than mid-calf; find another route. • Thoroughly investigate area to find safest crossings. • Wear appropriate foot gear for stream crossings. • It is safer to wade through water, rather than rock hop across a stream trying to keep your boots dry. • Unbuckle your pack and be prepared to jettison gear should you lose your balance or fall in. • Use a sturdy pole or walking stick for balance.
Working in heat, humidity, or cold	Heat exhaustion, sunburn, dehydration, hypothermia	• Evaluate the weather forecast each morning and plan field work accordingly. • Carry and drink plenty of water. • Take extra breaks during extreme weather events. Adjust the work routine to minimize exposure to extreme heat and humidity. • Take adequate garments for all possible weather conditions. Choose clothing that will keep you warm even if it gets wet.

Appendix S1.B. Job Safety Analysis (continued).

Tasks	**Potential Hazards**	**Recommended Action or Procedure**
Hazard trees	Being struck by falling trees or branches	• Look up. Be alert for widow-makers, storm damaged trees with large broken limbs, and unstable standing dead trees. • Do not spend extended time in an area with hazard trees.
Carrying a pack and other equipment	Injuries from improper packing, adjustment, and lifting of backpacks. Injuries from improper carrying of gear	• Learn how to properly pack, adjust, lift, and carry a pack. • When hand-carrying gear, keep one hand free. • If carrying long equipment, be aware of other people and never swing around quickly. Avoid allowing a long piece of equipment to project up and behind you, where you cannot see it.
General operation of a vehicle	Injuries from vehicle accident; Damage to vehicle	• Perform pre-operational check of vehicle (oil, tire pressure, tire condition, fluids, wipers, brakes, lights, gas, etc.). Report all needed repairs to the crew leader or supervisor promptly. • Do not use the vehicle if it is unsafe. • Wear seat belts with shoulder harnesses whenever vehicle is in motion. • Do not use cell phones or text while driving. • Only NPS employees, volunteers or authorized cooperators and contractors are allowed to operate or ride in a government vehicle. • Ensure full visibility from all windows and mirrors. Clean windshield regularly. • Always ride inside the vehicle. • Properly store and secure all tools, equipment, and cargo so that they will not shift during sudden starts or stops. • Plan your travel before you start. Know your route. • Practice defensive driving; be alert to potential hazards. • Obey all traffic laws and speed limits. • Adjust speed to changing weather or traffic conditions • Allow adequate following/stopping distance. • Avoid distractions such as eating while driving. • Be alert for pedestrians or bicyclists using roadways. • Be watchful for wildlife crossing roads, especially at early morning, dusk, and after dark. • Do NOT drive if fatigued. Stay alert!

Appendix S1.C. Safety Forms

Safety Acknowledgment Form

By signing below, I certify that I have read the safety section of the Volunteer Training Manual and the Phenology Monitoring Job Safety Analysis. I have shared any safety concerns or suggestions with the park Natural Resource Manager and they have been addressed to my satisfaction.

Print Name: _____

Signature: _____

Date: _____

Please return this form, along with the completed and signed NPS Agreement for Individual Voluntary Services, to the park Natural Resource Manager.

These forms only need to be completed once for each volunteer, prior to any field monitoring activities. An annual review of the Volunteer Training Manual and Job Safety Analysis is recommended for all volunteers.

Appendix S1.C. Safety Forms (continued).

Phenology Monitoring Safety Checklist

One month to one week before field work

Complete volunteer form and JSA acknowledgment and return to park Natural Resource Manager (one-time requirement)
Contact park Natural Resource Manager with seasonal schedule of monitoring
Discuss safety issues and bring up any concerns with park Natural Resource Manager
- Safety and emergency procedures
- Emergency contact(s)
- Assistance finding monitoring partner for remote or hard to access sites

Verify that you have needed gear
- Clipboard, data sheets, timer, pens/pencils
- Cell phone or other communication device (e.g., SPOT GPS Messenger at Acadia)
- Suitable field clothes and personal gear (e.g., insect repellent, food, water, rain gear)
- First aid kit (highly recommended)
- Camera and audio recorder gear and supplies, if conducting photo or acoustic monitoring

One to two days before field work

Complete trip plan for remote or hard to access sites and send it to the park Natural Resource Manager or designated individual
If using SPOT GPS Messenger or Personal Locator Beacon at ACAD, check out the equipment and review procedures, and send trip plan to NETN staff responsible for tracking traffic from these devices
Verify that the trip plan has been received
Check weather forecast and adjust plans accordingly

Day of field work

Notify park Natural Resource Manager or designated individual (RM/DI) of any changes to your plans to visit remote or hard to access sites
Notify a trusted person (spouse, friend, co-worker, etc.) of your planned visit to designated, accessible park site
Check in on arrival to remote or hard to access site (if requested by park Natural Resource Manager or designated individual)
Conduct field work
Check in with RM/DI after field work to remote or hard to access site – ***DO NOT FORGET!***

Appendix S1.C. Safety Forms (continued).

Phenology Monitoring Trip Plan for Remote or Hard to Access Sites

This form must be completed and e-mailed to the park resource manager (or other designated individual) in advance of your monitoring trip to a remote or hard to access site. If you are monitoring a route at Acadia and will be borrowing the NETN SPOT GPS Messenger and Personal Locator Beacon, NETN staff will need a copy of this trip plan and contact information for the individual who will be serving as your official check-in.

Name of monitor:

Cell phone number:

Home phone number:

Name of monitoring partner:

Partner cell phone number:

Partner home phone number:

Date of trip:

Start time:

End time:

Check-in time:

Warning: if you do not check in by this time, an attempt will be made to reach you by phone; if you do not respond, emergency services will be notified. Do not forget to check in!

Vehicle make, model, and license plate:

Planned parking location(s):

Route to be monitored:

Note: the person receiving this trip plan must have a map of the route.

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
1.00	November 2012	Brian Mitchell	Adapted from NETN Landbird Protocol SOP 1	New SOP

SOP 2 – Site Selection and Setup

Northeast Temperate Network
Version 1.23

Overview

Within each participating park, phenology observation occurs in selected sites within core or optional park habitats. NETN follows recommendations of the USA National Phenology Network (USA-NPN) for site and individual plant selection with some modifications, as described herein. Due to the use of volunteer monitors and the high sampling frequency needed for phenological observation, sites are selected for convenience of access and presence of recommended species, as well as representation of local conditions. Acceptable marking procedures vary by park.

Monitored habitats and species

Within each park or APPA region, monitoring occurs at select sites in core or optional habitats designated for phenology monitoring (Table S2.1). The two core habitats (vernal pools and northern hardwood forest) are monitored at all NETN parks except BOHA and SAIR which do not contain those habitats. In addition, park staff may choose to monitor optional habitats occurring in that park.

Table S2.1. Core and optional habitats for phenology monitoring within NETN parks. Core habitats are shown in bold. The two core habitats are widespread and ecologically important within most NETN parks.

	ACAD	APPA	BOHA	MABI	MIMA	MORR	ROVA	SAIR	SAGA	SARA	WEFA
Vernal pools	x	x		x	x	x	x		x	x	X[1]
Northern hardwood forest	x	x		x	x	x	x		x	x	x
Spruce-fir forest	x	x									
Alpine and subalpine		x									
Grassland and Open Fields	x		x		x	x	x			x	x
Permanent freshwater wetland	x						x	x			
Coastline	x		x								

[1]WEFA does not have true vernal pools, but does have pools where amphibians breed.

Within these habitats, fifteen plant species and twelve animal species are recommended for monitoring (Table S2.2). Staff at participating parks choose species from the recommended list that are of interest and present in accessible locations at their park. As a guideline, NETN suggests each park focus on only four or five key species per park in order to obtain a sufficient number of observations per species, focusing first on key species in core habitats. We focus network-wide efforts on a short list of selected species in order to provide sufficient data to determine trends.

Site selection

At each park, at least three sites are designated for phenology monitoring within each monitored habitat. A site is the area which is searched for a monitored animal species, and which encompasses any plants selected to monitor. Sites are selected and setup by program staff or collaborators. However, in some cases volunteers may collaborate with park staff to identify sites that are both convenient and

appropriate for monitoring. At each site, multiple methods may be used, and multiple observers contribute observations at most sites. In some cases, automated monitoring occurs at sites which are also observed by volunteer monitors; this provides a useful quality control check on volunteer observations. However, sensitive or hard to access sites may be monitored by automatic recording only.

Table S2.2. Plant and animal species recommended for monitoring within NETN core and optional park habitats. Core habitats are shown in bold.

Habitat	Plants	Animals
Vernal pools		Spotted salamander *(Ambystoma maculatum)* Spring peeper *(Pseudacris crucifer)* Wood frog *(Rana sylvatica)*
Northern hardwood forest	Garlic mustard *(Alliaria petiolata)* White wood aster *(Eurybia divaricata)* Sugar maple *(Acer saccharum)* Red maple *(Acer rubrum)*	Eastern tent caterpillar *(Malacosoma americanum)* Ovenbird *(Seiurus aurocapillus)*
Spruce-fir forest Alpine and subalpine	Bunchberry *(Cornus canadensis)* Painted trillium *(Trillium undulatum)* Hobblebush *(Viburnum lantanoides)* Balsam fir *(Abies balsamea)*	White-throated sparrow *(Zonotrichia albicollis)* Winter wren *(Troglodytes hiemalis; Spruce-fir forest only)*
Grassland and Open Fields	Common milkweed *(Asclepias syriaca)* Rough-stemmed goldenrod *(Solidago rugosa)*	Bobolink *(Dolichonyx oryzivorus)* Red-winged blackbird *(Agelaius phoeniceus)* Monarch butterfly *(Danaus plexippus)*
Permanent freshwater wetland	Red maple *(Acer rubrum)* Marsh marigold *(Caltha palustris)* Purple loosestrife *(Lythrum salicaria)*	Common loon *(Gavia immer)* Wood frog *(Rana sylvatica)*
Coastline	Beach pea *(Lathyrus japonicus)* Beach rose *(Rosa rugosa)* Rockweed *(Ascophyllum nodosum)*	Common loon *(Gavia immer)* Great black-backed gull *(Larus marinus)*

The size of monitoring sites varies depending upon the habitat and species to be monitored. For sites in which only plants are monitored, the site should encompass the area immediately around the plants, and conditions should be relatively uniform within the site. For sites in which animals are monitored, the site should encompass a walking route from which one can see or hear the species of interest. USA-NPN recommends that sites should be no larger than 6 hectares (about 15 acres, or 250 x 250 meters). This upper limit constrains sites from being larger than a MODIS pixel. In an open grassland or near a body of water, a site might be the maximum recommended size (15 acres) because it is possible to identify animals that are far away. In contrast, a site in a forest would probably be smaller because it would not be possible to identify species at large distances. Even if it is possible to identify animals over a large area, the area must be divided into different sites if it includes habitats that are obviously different. For instance, if making observations at a pond in a meadow, the pond and the meadow must be registered as separate sites. At BOHA, an island may be considered a single site.

Due to the use of volunteer monitors and the high sampling frequency needed for phenological observation, sites are selected for convenience of access and presence of monitored species, as well as lack of human disturbance, representation of local conditions, and uniformity. This approach allows NETN to detect temporal trends in phenological change for key species at these “index” sites. NETN assumes temporal phenological trends at index sites are indicative of change at other locations within these park habitats. However, it will not be possible to extrapolate data from these index sites to other locations using this non-random sample design. This is a significant limitation of the selected sample

design, but one which is warranted in this case. The selected "index site" design meets NETN sampling objectives to detect temporal change, while accommodating the need to monitor conveniently located sites.

Staff use the following criteria to select sites for phenology monitoring:

Convenient: Sites must be convenient and accessible enough to visit at least weekly throughout the growing season and in all weather. An ideal location for a designated site is near a popular trail or visitor center. However, designated sites for automated monitoring may be located in a remote or hard to access area of interest.

Undisturbed: The site should be sheltered from human disturbance. Avoid sites adjacent to a building, pavement, farm, or other human land-use, or areas affected by fertilizers, pesticides, irrigation or watering by humans, or a man-made heat-island or other climatic disturbance.

Representative: As much as possible, sites are typical of the vegetation and climate of the target habitat. Select sites which are neither excessively steep, flat, or dry compared to the habitat type as found in the park. In forested areas, select sites that are generally similar to the surrounding forest, reflecting the overall canopy composition and structure.

Uniform: Conditions should be relatively uniform across the site. If species of interest are found in two adjacent but distinct habitats, they are documented as separate sites. For example, a vernal pool occurring within a northern hardwood forest is documented as a separate site from the forest.

Species presence: The site must contain the species to be monitored. For animals, the site lies within an appropriate habitat for that species, and encompasses a stationary location or walking route from which the species of interest can be seen or heard.

Site Naming

Sites are assigned names, unique within the park, by park staff or cooperators. These are typically text strings that describe the location or a feature of the site. When a site is registered online into the USA-NPN's National Phenology Database using *Nature's Notebook*, the site is assigned a unique four-digit identification number, which is used to identify this site during data analysis, and for data management of audio and image data files.

Selection of Individual Plants

Individual plants are selected for monitoring by program staff or cooperators, or by volunteer monitors if allowed at that park. At each site, at least three individual plants of each monitored species are selected for monitoring. Observing three individuals at each site is best for understanding how phenology varies among individuals at a site.

Individual plants are selected following these USA-NPN guidelines. Selected plants should appear to be healthy, undamaged, and free of pests and disease. Selected plants should also not be closer than 6 meters (about 20 feet) to a road or building.

Selected plants of the same species at a site should be growing in a similar environment but not be direct neighbors or closer than two to three times the width of the plant's canopy. In a forest, selected trees should occupy similar positions in the canopy and habitats on the ground.

If observing annual plants (which only survive one growing season) or biennials (such as garlic mustard, which survive for two growing seasons), the first or the last seedling to emerge in the spring are avoided, since they may not be representative of the larger population at a site. If a plant grows in a large mass where it is difficult to distinguish or mark individuals, staff may choose to designate the plant as a "patch". If monitoring as a patch, it is important to correctly mark and register the patch as described below.

It is important that plants are correctly identified to species before data is submitted. Species recommended for monitoring by this protocol are readily identifiable to species using information provided during training or in field guides. Program staff should verify correct identification of all marked individual plants.

Select Walking Route

It is impractical for volunteers to mark and monitor individual animals, so animal species are monitored as a population at each site. Animals are observed along a marked walking route through each site. Program staff or cooperators select and mark a single route through each site. This route should encompass areas where the animal species of interest have been seen or heard, but should avoid disturbance to nesting sites or sensitive areas.

Marking

Marking is used to uniquely identify and delineate each site, walking route and monitored plant. Specific marking conventions are determined by park staff at each participating park, in keeping with aesthetic standards for the park. If allowed by park staff, individual plants may be selected and marked at a designated site by volunteers. Markers are replaced periodically as they weather and become damaged or unreadable.

A general marking procedure is included here, but each park decides what specific marking is acceptable. The center and corners of a site, or a specific route for animal observation may be marked with stakes in the ground or flagging tape on tree or shrub trunks or branches. The markers must display a unique label or name for the site, location or route written using permanent ink. Individual animals are not marked in this monitoring program.

Individual trees and shrubs may be marked by attaching flagging tape or a small, inconspicuous tag to the trunk or a branch. Forbs may be marked with a labeled stick or skewers placed in the ground next to the plant. Each plant marker must display a unique label or name for the plant written using permanent ink. For example, the flagging on a tree could be labeled “Red maple 1” or “Big red.” Marking must not change the growing conditions of the plant. For example, avoid placing a broad stake in a location where it could shade or cause root damage to a small plant.

To set up a “patch”, mark the four corners of a square within the area the species takes up over the ground. USA-NPN recommends a square that is 3 feet (or 1 meter) on each side, but the square can be smaller.

Register Site Online at *Nature’s Notebook*

After a site is selected, park staff register the site online at *Nature’s Notebook* at www.nn.usanpn.org. *Nature’s Notebook* is an online plant and animal phenology observation program of the USA National Phenology Network. Most designated sites in NETN parks are “shared sites” for which multiple

observers submit data. Note that a shared site is different from a "public site" (a site at which anyone could register and submit data observations). Shared sites are administered by park coordinators in coordination with USA-NPN, and are accessed by a discrete set of trained observers. Alternatively, any site at which informational displays are used to attract park visitors to make one-time or initial observations must be registered as a "public site" to enable any visitor to submit an observation for that site into *Nature's Notebook*.

To begin, the park coordinator registers a new partner group with USA-NPN NCO staff by emailing nco@usanpn.org with the name of the network (NETN), the park (ie, ACAD), and a list of existing users who will submit observations at this park. Once the group is established, the park coordinator adds shared sites and monitored plants online. These sites and plants are accessible online by all members of the group. New monitors join the group online by choosing "Edit" from their *Nature's Notebook* account homepage, then selecting a park group from the list of partner organizations. To do this, first choose "National Park Service" as the Partner Organization, then from the next window choose "Northeast Temperate Network", then choose a specific park (ACAD, APPA, BOHA, MABI, MORR, ROVA, SAIR, SARA or WEFA). Then, *Nature's Notebook* NCO staff notify the park coordinator that a new group member wishes to join, and the coordinator must recognize and accept the member before access is granted.

Park coordinators use the "Manage Users" link in *Nature's Notebook* to view information about group members.

Informational Displays

At some monitoring sites, informational displays may be used to attract park visitors to make one-time or initial observations. Poster displays and/or handouts provide USA-NPN information on the species and phenophases to be monitored at that site, and *Nature's Notebook* datasheets are provided. These materials are self-explanatory to enable one-time observers to make a contribution without training. Sites with informational displays must be registered in *Nature's Notebook* as "public sites" (rather than "shared sites"), so that any visitor is able to submit an observation for that site.

Data Collection

Data describing the site is collected during plot setup by park staff or cooperators using the Site Datasheet found in Appendix A below, and entered online into USA-NPN's National Phenology Database using *Nature's Notebook*. Data describing an individual plant is collected whenever a new individual is selected and marked for monitoring. Plant registration info can be collected using the Plant Registration Datasheet in Appendix A below, and entered online in the same manner as site information. Site and plant registration information is updated annually, or if conditions change. We follow the conventions of USA-NPN for site and plant data collection (USA-NPN Technical Information Sheet. July 2012. Supplementary Organismal and Site-specific Information Collected via *Nature's Notebook,* Version 1.0, http://www.usanpn.org/files/shared/files/USA-NPN_suppl_info_tech_info_sheet_v1.0.pdf).

If monitoring a plant as a patch, it is important to report this fact when registering the plant in *Nature's Notebook*. Click the check box for "Patch?" to indicate it is a patch rather than a single individual, and report the size of the patch.

Revision History

Version #	Date	Revised by	Changes	Justification
1.00	July 2010	Geri Tierney		
1.01	Sept 2010	Geri Tierney	Added paragraph on informational displays. Editorial changes.	
1.02	Oct 2010	Geri Tierney	Adjusted text on individual plant selection. Clarified reason for upper limit on site size.	
1.10	April 2011	Brian Mitchell and Geri Tierney	Added section on monitored habitats. Removed option for volunteer to choose custom site. Adjusted number of sites per park habitat to be >= 3, and number of plants per site to be >= 3.Clarified that sites are not randomly selected. Editorial changes.	
1.11	March 2012	Geri Tierney	Removed text describing casual observer methods. Add instruction for registering site at USA-NPN, and designating multi-observer site. Added section for registering plants, including patch monitoring. Editorial changes.	
1.2	Nov 2012	Geri Tierney	Removed metadata field description and replaced with reference to USA-NPN methods and technical information sheet. Added USA-NPN recommended *Nature's Notebook* text. Added guidance to park managers on species selection and walking route. Editorial changes.	
1.21	Nov 2012	Geri Tierney	Added patch monitoring instructions. Added datasheets for collection of site data and plant registration information. Added site naming guidelines. Reinserted informational displays to attract one-time or initial observers at "public sites".	
1.22	Jan 2013	Ellen Denny, Geri Tierney	Edited references to USA-NPN. Clarified monitoring frequency. Added patch size to datasheet. Editorial changes.	
1.23	March 2013	Geri Tierney	Reformatted plant registration datasheet to accept 3 plants per sheet.	

Appendix S2.A. Datasheets

NETN Phenology – Site Datasheet, Version 1.00

These USA-NPN data fields are recorded when sites are setup for monitoring, and entered online into USA-NPN's National Phenology Database via *Nature's Notebook*. Update annually, or if conditions change.

Station code or site name _____ ***Date recorded*** _____

Latitude/Longitude _____°/_____°

Record at the center of the site in decimal degrees WGS84. Record to four decimal places (eg, 42.4910°).

Elevation _____ **feet** above sea level (from a GIS layer or topo map).

Development. The degree of development surrounding the site can best be described as:

- Suburban: Sites surrounded mostly by houses with yards.
- ☐ Rural: Surrounded by farms or mowed or grazed pastures, or near a rural residence or ranchette.
- ☐ Wildlands or semi-wildlands: Within natural habitats, managed woodlands, or grazed rangelands.
- ☐ Other (describe in comments)

Habitat type. Record the habitat as:

- ☐ Landscaped area (eg, garden, lawn)
- ☐ Agricultural field, cropland or pasture
- ☐ Orchard or tree farm
- ☐ Grassland or meadow
- ☐ Beach, dune, salt flat or barren land
- ☐ Shrubland, shrub thicket, or shrubby field
- ☐ Forest or woodland
- ☐ Open wetland (eg, marsh or bog)
- ☐ Forested wetland (such as swamp)
- ☐ Other (describe in comments)

Distance to Road _____ feet / yards/ miles (**circle unit of measure**)

Estimate the distance in feet, yards or miles from the center of your site, to the nearest road.

Distance to Permanent Body of Water _____ feet / yards/ miles (**circle unit of measure**)

Estimate the distance from the center of your site to the edge of the nearest permanent body of water.

Site area _____ *acres* / square feet / square yards (**circle unit of measure**)

Record the approximate area of the site in acres, square feet or square yards.

Site Comments. Please include any useful information about your site, including descriptions of any feature described as "other" (such as habitat type, tree cover, domesticated animals, or features that attract animals).

Additional questions for plant sites:

Tree cover. If there are trees at this site, they can best be described as:

- ☐ Mostly evergreen trees (eg, pine or live oak)
- ☐ Mostly deciduous trees (eg, maple or larch)
- ☐ A mixture of evergreen and deciduous trees
- ☐ Other (describe in comments)

Slope. Is the site on or near a slope?

- ☐ No, the surrounding terrain is relatively flat
- ☐ Yes, on the top of the slope or on a ridge
- ☐ Yes, in the middle of the slope
- ☐ Yes, bottom of the slope or valley

Aspect. The slope at this site faces:

☐ N ☐ NE ☐ E ☐ SE ☐ S ☐ SW ☐ W ☐ N

Additional questions for animal sites:

Domesticated animals. Which, if any, domesticated animals are seen outside at the site.

☐ Cats ☐ Dogs ☐ Other (specify in comments)

Garden. Is there a flower or vegetable garden maintained at the site?

☐ Yes ☐ No ☐ Unknown

Food, water or nest box. Are feeders, nest boxes or any other features designed to attract animals at the site?

- ☐ Bird feeder
- ☐ Nest box
- ☐ Fruit
- ☐ Fountain or artificial pond
- ☐ Other (describe in comments

NETN Phenology – Plant Registration, Version 1.00

Record when individual plants are selected for monitoring, and enter online into USA-NPN's *Nature's Notebook*. Update annually, or if conditions change.

Station code or site name _____ ***Date recorded*** _____

	Plant 1	**Plant 2**	**Plant 3**
Species – common name			
Nickname			
Patch (y or n)	Y or N	Y or N	Y or N
Patch size			
Patch size units	sq. ft. OR sq m.	sq. ft. OR sq m.	sq. ft. OR sq m.
Shade status			
Wild?	? Y N	? Y N	? Y N
Watered?	? Y N	? Y N	? Y N
Fertilized?	? Y N	? Y N	? Y N
Gender?	? M F Both	? M F Both	? M F Both
Comments			

Nickname. Assign a unique name or code to each plant to distinguish among them. For example, if you choose three red maple individuals at this site, you could nickname them red maple-1, red maple-2, and red maple-3.

Patch. Is this a monitored patch? Most NETN monitoring will be on individual plants, but in some cases a patch may be monitored. Monitoring a patch can be easier for plants where individuals are hard to distinguish, such as groundcover and some grasses

Patch size. If monitoring a patch, mark the corners of the patch and always monitor within the marked area. Measure and record patch area as square feet or square meters.

Patch size units. If monitoring a patch, circle unit of measure used (square feet or square meters).

Shade status. Which of the following best describes the shade status of each individual?
For **small plants and shrubs**, record as Full sun, Mostly sun, Half shade, Mostly shade, or Full shade.
For **trees**, record as Open-grown tree (grows under open sky, unshaded by other trees), Forest canopy tree (grows next to other trees of similar height, forming a continuous canopy), or Forest understory tree (grows in shade below taller trees).

Wild? Does this individual plant appear to be a wild plant, growing from a seed brought in naturally by wind, water, birds or animals? Most horticultural plants in gardens and parks are intentionally planted by humans and therefore not wild, although often so-called "weeds" were brought in by natural forces and can be considered wild.

Watered? Does this individual plant get supplemental water? Ideally, plants monitored by NETN will not be given supplemental water. Record "?" for unknown, "Y" for yes, or "N" for no.

Fertilized? Does this individual plant get supplemental fertilizer? This is likely to apply only to plants in a park or garden. Ideally, plants monitored by NETN will not be fertilized. Record "?" for unknown, "Y" for yes, or "N" for no.

Gender? If this plant species is dioecious (has male and female flowers on separate plants), indicate whether this individual has only male flowers, only female flowers or both types. Of the species targeted for NETN monitoring, rockweed is dioecious, and red maple and sugar maple may be dioecious. All other NETN species have both male and female flowers on the same plant. Record "?" for unknown, "M" for male, "F" for female, or "Both".

Comments. Record any additional features that seem important, such as anything that makes this plant unusual.

SOP 3 – Observer Recruitment and Training

Northeast Temperate Network

Version 1.11

Overview

This SOP describes practices for recruiting, training and supporting observers for the NETN Phenology Monitoring Program. This program operates with both staff and volunteer observers. NETN has developed and maintains a Phenology Observer Training Manual which is an accessory document to this protocol, and can be obtained online at the NETN website (http://science.nature.nps.gov/im/units/netn/monitor/programs/phenology/phenology.cfm) or from NETN staff. This SOP will be updated annually to improve training and support procedures, and to incorporate useful suggestions by observers and coordinators.

Recruiting volunteers

Phenology monitoring is interesting and methods are straightforward, making it suitable for participation by volunteer observers. Many opportunities exist for recruiting volunteers to participate in this program. Park coordinators may recruit volunteer observers using these methods:

- Invitations to existing volunteers and trail club members
- Announcements at NPS and park-related events (Trail days, etc.)
- Postings in local media
- Postings using social media (Facebook, Twitter, etc.)
- Solicitations on associated websites (ATC, AMC, USA NPN, NETN, park websites, etc.)
- Contact with local native plant clubs, nature centers and colleges
- Informational displays and flyers at visitor centers and facilities in parks and along APPA

Most volunteers are trained to submit repeat observations of plant or animal phenology. Participation as an observer requires a moderate (every other day or at least weekly) time commitment, some familiarity with plant or animal identification and observation, and the ability to keep careful records. Training procedures for observers are provided in the NETN Phenology Observer Training Manual.

In addition, volunteers with technical skills and interest may be trained to maintain automated recording devices and participate in processing of audio or photographic data. Training for these tasks is more involved and specific, and is not described in this SOP. Rather, training at this level occurs one-on-one with NPS staff or cooperators.

Training observers

Observers that are able and willing to make repeat observations attend a 1- to 3- hour training session held annually at each participating park and within each APPA region. When possible, the NETN Science Communication Specialist hosts this training during annual park visits.

Alternatively, park or regional coordinators plan and host this event each year. Training focuses on understanding material in the NETN Phenology Observer Training Manual, and includes:

- A brief introduction to phenology and this program
- Location of designated monitoring sites and description of site marking at that park
- Plants and animals to observe at that park
- How to choose and mark plants (if allowed at that park)
- How to create an online account in *Nature's Notebook*
- How and when to make observations
- How to record and submit data
- A complete example of making phenology observation
- A chance to ask questions

Online Training Materials

Useful online training materials are available on USA- NPN's *Nature's Notebook* website (www.usanpn.org/nn/training_videos.). The following topics are presented online both as PowerPoint presentations, and as training videos.

- Record plant observations
- Record animal observations
- Enter plant observations online
- Enter animal observations online

Additional training materials available on this website are not used as part of this program, because procedures in our parks differ from general USA-NPN instructions. It is important that park coordinators stress to all observers that within national parks, monitoring only occurs at designated sites, and that any marking of individual plants, if allowed, strictly follows rules for marking at that particular park. In this program, observers choose among species selected for monitoring at that park.

Feedback

Observers are surveyed annually to assess satisfaction and solicit suggestions for improving the program, including training and data collection. These suggestions are carefully considered, and useful suggestions are incorporated into the program.

In addition, sharing program results with observers aids in maintaining enthusiasm and retaining volunteers. NETN prepares periodic Resource Briefs describing the status of this Phenology Monitoring Program. Briefs are available online at the NETN website (http://science.nature.nps.gov/im/units/netn/education/outreach.cfm), and may be distributed to volunteers. In addition, the USA-NPN website interface, includes functions to allow volunteers to visualize and download data submitted by their network of observers and others across the country, as well as access USA-NPN reports.

Revision History

Version #	Date	Revised by	Changes	Justification
1.00	July 2010	Geri Tierney		
1.01	Sept 2010	Geri Tierney	Editorial changes	
1.02	April 2011	Brian Mitchell, Geri Tierney	Clarified that training for volunteers assisting with automated recording is not described in this SOP, and that volunteers may mark plants but not sites. Editorial changes	
1.10	Dec 2011	Geri Tierney	Removed references to participation by untrained observers. Added additional USA-NPN training materials.	
1.11	Jan 2013	Ellen Denny, Geri Tierney	Editorial changes.	

SOP 4 – Observation

Northeast Temperate Network
Version 1.23

Overview

Monitors observe the phenology of plants and animals at designated sites in participating NETN parks using the phenophases, datasheets, and infrastructure provided by the USA National Phenological Network (USA-NPN), with some modification as described herein. Observations are made by two groups of monitors: a) park visitors recruited onsite to make one-time or initial observations; and b) trained volunteers or staff who submit repeat observations. These data are used to determine trends in phenological change for key species at index sites, and assist park managers with the detection and mitigation of the effects of climate change on park resources. Observers submit data online directly into *Nature's Notebook* (www.nn.usanpn.org). *Nature's Notebook* is an online plant and animal phenology observation program of the USA National Phenology Network.

Equipment and Supplies

- A *Nature's Notebook* datasheet packet including Phenophase Definition Sheets and Datasheets for each monitored species, an Animal Checklist (if observing animals) and Cover Sheets for each site (from www.nn.usanpn.org, or from park coordinator at BOHA only)
- Clipboard (optional) and pencil
- Binoculars (optional, but encouraged for observing animals and tall trees)
- Park approved plant marking equipment for first trip (if allowed to select plants)
- Map of site (if provided by park)
- Photo guide to phenophases (BOHA only)

Procedure

Park visitors may be recruited onsite by informational displays to make one-time or initial observations in participating parks. Visitors are invited to review USA-NPN phenophase descriptions and instructions and to make observations on marked individual plants. Participants record observations on *Nature's Notebook* datasheets provided onsite, and subsequently submit observations online in *Nature's Notebook*.

Monitors making repeat observations first attend a 1- to 3-hour training session as described in the Observer Recruitment and Training SOP. The training includes a description of monitored habitats and specific monitoring sites available at that park, a list of plant and animal species available for monitoring at that park, and guidance on making observations. The NETN Phenology Observer Training Manual provides user-friendly instructions for volunteer monitors.

Trained monitors visit their site(s) at least once per week, but ideally every other day during periods of rapid phenological change, such as in the spring or fall. Observations can be made at any time of day, but monitors are encouraged to visits sites consistently around the same time of day. This is because some animal species tend to be more active at certain times of day and plant activity can vary over the course of the day.

To monitor plants, one to three marked individuals of each monitored plant species are observed during each visit. Observing three individuals at each site is best for understanding how phenology varies among individuals at a site; but data from only one or two individuals is useful as well. Each individual plant is observed for each phenophase during a visit, and data is recorded on *Nature's Notebook* datasheets. For most plant phenophases, observers also check and **report on phenophase intensity** (or abundance), like the number of flowers or percentage of open flowers seen. Phenophase abundance choices are described on *Nature's Notebook* Phenophase Definition sheets for each species. Observers are encouraged to use binoculars to see phenophases in tall trees.

Herbaceous plants growing in clumps may be monitored as a patch rather than an individual. Setup a patch as directed in the Site Selection and Setup SOP, and make sure to properly designate the patch in *Nature's Notebook* by clicking the check box for "Patch?" when registering the plant, and report patch size. Evaluate the phenophases in the patch as if all of the stems in the patch are a single individual.

If an individual plant dies or is obviously declining in health (when others of the same species around it are still healthy), park staff choose a new individual as described in the Site Selection and Setup SOP, and report the death of the previous individual. Never substitute observations from a nearby, healthy individual when a marked plant is missing, dead or declining. Instead, mark and register the new individual plant and report observations for the new, monitored plant.

To observe animals, monitors look and listen for the species on their Animal Checklist during a walk along a designated transect through the site. NETN uses only the 'walk' method of animal observation. The standard search time will vary among sites, as directed by park staff. On most days, monitors will observe few, if any, of the animal species on their list. This negative data is very useful, and monitors continue to record on the Animal Checklist that they did not observe the species on that date. Phenophase data is only filled out for species which were observed during that visit.

Observers record data in a *Nature's Notebook* datasheet package, and submit data online directly into *Nature's Notebook* (at www.nn.usanpn.org); as described in the NETN Phenology Observer Training Manual.

Revision History

Version #	Date	Revised by	Changes	Justification
1.00	July 2010	Geri Tierney		
1.01	Sept 2010	Geri Tierney	Adjusted procedure for one-time observation. Editorial changes.	
1.02	Oct 2010	Geri Tierney	Adjusted "?" observation definitions to match NPN change. Edited text for individual plant selection.	
1.03	Nov 2010	Geri Tierney	Logbooks will not collect personal information, but will include time and comments.	
1.10	April 2011	Brian Mitchell, Geri Tierney	Revised to match US-NPN 2011 procedures, including abundance. Dropped stationary and area search options for animal observation in favor of single walk. Moved time of observation to comments for animals only. Eliminated question on site flooding. Editorial changes.	
1.11	May 2012	Geri Tierney	Revised to remove casual observers. Updated intensity category example for 2012. Use of binoculars in tall trees encouraged.	
1.21	Sept 2012	Geri Tierney	Removed detailed description of NPN data collection, referring instead to current data sheets. Added USA-NPN recommended *Nature's Notebook* text. Added patch monitoring instructions. Editorial changes.	
1.22	Nov 2012	Geri Tierney	Reinserted one-time or initial observations by untrained observers.	
1.23	Jan 2013	Ellen Denny, Geri Tierney	Edited references to USA-NPN. Clarified monitoring frequency. Editorial changes.	Frequent monitoring only needed during rapid change.

SOP 5 – Building an Autonomous Recording Unit

Northeast Temperate Network
Version 1.00

Overview

Automated audio recording can be an important data source for long-term phenological research, providing a consistent and objective stream of data at optimal frequency in both accessible and remote locations. This protocol includes two options for implementing automated audio recording: 1) using commercial autonomous recording units (ARUs; the Wildlife Acoustics Song Meter), and 2) building less expensive ARUs using off-the-shelf components. The choice of whether to implement automated audio monitoring for phenology and which recording option to use is up to the individual parks. Commercial devices are more convenient, more powerful, and come with a certain amount of technical support, but they also have a higher price tag (about $800 for the unit, batteries, and memory cards). Do-it-yourself ARUs are significantly cheaper and offer a potential learning experience (e.g., for a high school science class), for about a quarter the price.

This SOP provides specific procedures for constructing an inexpensive autonomous recording unit (ARU) using an Olympus digital audio recorder housed within a weatherproof Pelican case and connected to an array of two microphones. Power is supplied by a battery pack of 4 D-cell batteries and data is stored on an SD card. The ARU is a compact, weather resistant, autonomous field recorder with three independent timer settings. It is designed to be temporarily attached to a tree or post using long cable ties, cable, straps, or rope, and the microphone is designed to hang 2-3' from the recorder. The recorder produces high quality, two-channel (left/right) MP3 or WAV recordings onto removable SD or microSD media. The channels are intended to be identical to provide redundancy in case of physical damage or water intrusion into one channel. A recorder's battery will allow deployment for as long as 28 days of 24-hour per day recording. As of 2012, media constraints allow for a maximum/equivalent of 13 days of 24-hour per day recording onto a 32GB SD or microSD card.

This procedure was developed by and Jon Katz and Corinne Brauer of the Vermont Cooperative Fish and Wildlife Research Unit at the University of Vermont.

Required Materials:

Qty	Description	Suggested source	Item #	URL	Estimated Cost[1]
1[2]	Olympus DM-420 Digital Voice Recorder OR Olympus DM-620 Digital Voice Recorder	Amazon.com	B002JTX87W OR 142665	http://www.amazon.com/Olympus-Digital-Voice-Recorder-DM-420/dp/B002JTX87W/ OR http://www.amazon.com/Olympus-142665-DM-620-Voice-Recorder/dp/B004S561V0/	$99.99 OR $149.00
2	Battery Holders, Snaps & Contacts 2 D W/8 24AWG LDS	Mouser.com	12BH121A-GR	http://mouser.com/ProductDetail/Eagle-Plastic-Devices/12BH121A-GR/?qs=sGAEpiMZZMupuRtfu7GC%252bdUGrIKBfc93ebWmxALgLTw%3d	$2.62
2[3]	Microphones, omnidirectional	Mouser.com OR Super Circuits	254-ECM640-RO OR PA3 / PA3-IL	http://mouser.com/ProductDetail/Kobitone/254-ECM640-RO/?qs=sGAEpiMZZMsYQx PYEnGVuKI2oUawXrSZjjuYNZ7QPDw%3d OR http://www.supercircuits.com/accessories/microphones/super-high-gain-micro-audio-system-pa3	$4.98 OR $19.98
0.1[4]	Communication Instrumentation Cable 2C 24AWG SHIELD, 100'	Mouser.com	602-2400C-100	http://mouser.com/ProductDetail/Alpha-Wire/2400C-SL005/?qs=sGAEpiMZZMsa6%252bU7AAQG5bpaGUIY64uY2lQNJ9zOBQ0%3d	$3.55
2	Phone Connectors PHONE 3.5MM MONO	Mouser.com	171-PA3291-1-E	http://www.mouser.com/ProductDetail/Kobiconn/171-PA3291-1-E/?qs=XuGxIpNJLigIU7CKCfGhgnUQdZJgeDw8Xn8tEAEwm0g%3d	$1.00
1	Phone Connectors 3.5MM Stereo	Mouser.com	161-3507-E	http://www.mouser.com/ProductDetail/Kobiconn/161-3507-E/?qs=itG3xFeL1F1sDGBg7GCnYakIr%252bj3wF%252b7Oi%252buskoQVEw%3d	$1.00
1	1120NF Guard Box Protector Watertight Case without Foam (Black)	B&H Photo www.bhphotovideo.com	PE1120B	http://www.bhphotovideo.com/c/product/150620-REG/Pelican_1120_001_110_1120_Case_without_Foam.html	$17.95
1	32GB microSDHC Memory Card	B&H Photo www.bhphotovideo.com	TRMSDC232GB	http://www.bhphotovideo.com/c/product/738454-REG/Transcend_TS32GUSDHC2_32GB_microSDHC_Card.html	$72.63
1[5]	32GB SDHC Memory card	B&H Photo www.bhphotovideo.com	KISDHC432GB	http://www.bhphotovideo.com/c/product/592772-REG/Kingston_SD4_32GB_32GB_SDHC_Memory_Card.html	$66.95
1[5]	microSD to SD adapter	Ameri-Rack Technology,Inc	PA-TFC1	http://www.ably.com.tw/pdt/viewpdt.asp?absp=3&cat=OTHERS	$24.35
4	MAHA PowerEx 1.2V 11000mAh D Cell NiMH Batteries	Zbattery.com	MH-2D110	http://www.zbattery.com/MAHA-PowerEx-1-2V-11000mAh-D-Cell-NiMH-Batteries-2-Card	$50.70

[1] Costs are for the quantity needed for one recording unit in 2011. In many cases, costs per recording unit can be reduced by buying in bulk.
[2] Two choices of recorder are listed; the DM-420 is the one used in units built by NETN to date. The DM-620 allows for recording in WAV, which requires more memory for a given recording length, but produces higher quality files.
[3] Two choices of microphones are listed; the microphones from Mouser.com are the ones used in units built by NETN to date. The NPS Night Skies and Natural Sounds Program highly recommends the PA3 microphone for its exceptional noise floor; use of this optional microphone may require some adjustment to the procedures below. Use of the PA3 microphones will also require an RCA to 3.5mm stereo plug adapter (about $5) and will save on some soldering work.
[4] Usually sold as a full roll rather than as bulk wire, but only 4'-10' is used in one recorder (see note in microphone construction section).
[5] Optional; purchase for media storage if microSD cards are undesirable or unavailable.

Additional Equipment to Purchase Locally

6” 18-gauge black wire
6” 18-gauge red wire
2x 3/8” dowel cut to 1 5/8” length
1 brass thumb tack
1 brass screw #4 x ½”
8 screws #6 x ¼”
Solder
3 deck screws, 1 ¼”
3x 4” cable ties
Waterproof glue
7” x 4.5” board of Lauan or similar ¼” lightweight plywood (oak or birch are more eco-friendly than lauan); MDF, HDF, or Homosote are not recommended due to moisture exposure
5” length of 2”x2” wood
7/32” steel rod cut to 6” length
Heat shrink tubing or electrical tape
28” of 1” wide double-sided Velcro strap
8” plastic dish
½” wire mesh or hardware cloth
6.5” x 10.5” Faux fur

Tools Required

Soldering iron
Diagonal pliers
Needle nose pliers
Wire stripper
Phillips #2 screwdriver
Electric drill
7/32” Drill bit
5/32” Drill bit
1/8” Drill bit
1/16” Drill bit
Swaging tool
Hacksaw
Sewing machine or needle and thread
Volt/ohm meter

Prepare the Pelican case

Drill a 7/32” hole through both long ribs on the hinge side of the box. Place the hole at least 1/8” from all edges; centering the hole 5/8” from the end of the rib and ¼” from the side should provide sufficient support. Pass the steel rod through the hole and use the swaging tool to crimp both ends so it cannot slip back out of the hole. Only a small amount of mushrooming is necessary to keep the rod in place. This preparation will

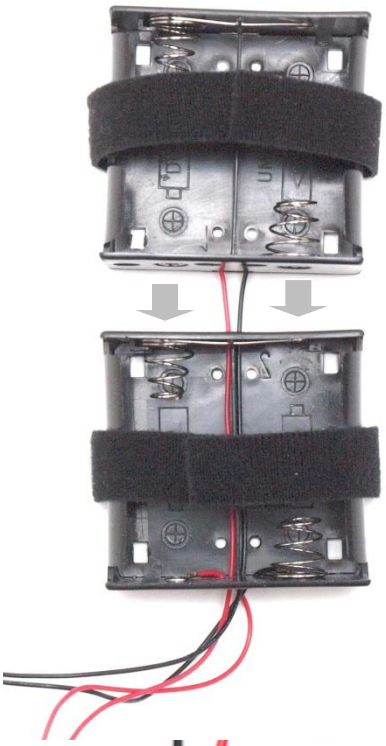
provide an anchor for fastening the case to a tree or other support.

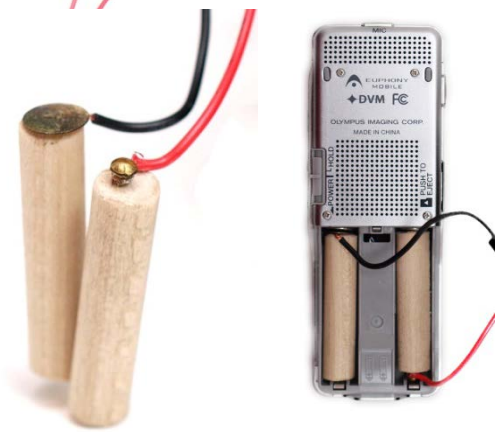
Prepare the recorder support

Insert two deck screws through the lauan or plywood backboard into the 2x2 support, fastening the length of 2x2 to the lower left corner of the lauan and leaving 1/8" along the left margin. Cut a 2.5" length of Velcro strap in half (lengthwise, to form 1/2" wide straps) and use a small screw to fasten one end of each Velcro strap to the 2x2 support 3/4" from the top on the left and right sides. Repeat this and fasten two more straps 3/4" from the bottom on both sides.

Prepare the battery holder

Stack two battery holders end to end, both with the wire leads pointing down. Pass the leads from the top holder through the lower holder so that the leads of both emerge from the lower holder. Cut two segments of Velcro strap 9" long and place one segment behind each battery holder so that it can loop around the front to secure the batteries in place. Use two screws in each holder to fasten each battery holder to the lauan back plate, allowing a ¼" margin between the edge of the holders and the edge of the 2x2 that is already screwed to the back plate. Use the wire cutters to trim the leads so they are the same length, and use the wire strippers to remove ¾" of insulation. Twist the two red leads together. Twist the two black leads together. Strip ¾" from the two lengths of 18 gauge wire and solder them to the respective colored leads. If using shrink-fit tubing to insulate connections, slip a 1.25" length onto each lead (covering the junction) and heat it with the soldering iron to shrink it. Strip ½" of insulation from the free end of the extended leads, twist the stranded wire of each lead into a coherent element, and make a 90 degree bend in the exposed wires. Solder the red lead to the brass screw by placing the 90 degree bend immediately below the head of the screw. Solder the black wire to the brass tack in the same fashion. Cut the dowel into two 1 5/8" pieces to match the size of a AAA battery. In the center of one end of a dowel piece insert the brass screw by holding the screw steady with a screwdriver and twisting the dowel in. In the center of an end of the other dowel push in the brass tack. Insert the dowels into the





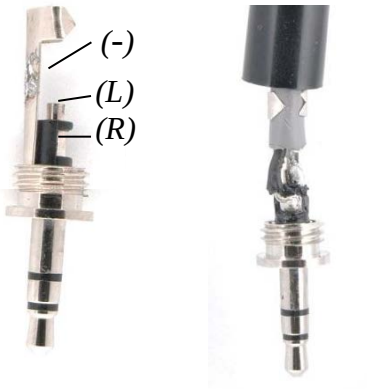
Be sure to properly align polarities!

recording units as they are oriented in the picture to the right (with polarities properly aligned). Insert four D batteries into the battery holders, and check that the recording unit powers on.

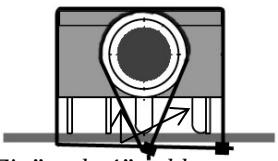
Prepare the internal audio connector

Cut a 13” section of shielded audio cable. Strip back 1” of the outer insulation and remove the mylar to expose the shield lead (image at right). Strip back 3/8” of each audio conductor. Orient the Pelican case with the hinge on the right, and the lid in front. Drill a 5/32” hole in the bottom center of the Pelican case and pass 2” of audio cable through. Solder one conductor to the (R) terminal and the other conductor to the (L) terminal of the female phono jack. Solder the shield to the (-) terminal. Drill three 1/8” holes in the Pelican case in a triangle beneath where the phono jack will sit, one under the threaded barrel and one to either side (see pattern below). Pass a 4” cable tie through the side holes and loop another through the hole beneath the barrel (see drawing below right). Use the cable ties to pull the phono jack tight against the Pelican case. On the other end of the audio cable slide the male phono plug housing onto the cable. Strip back 1/2” of the outer insulation, remove the mylar the shield, isolate the shield lead, and strip back 3/8” of each audio conductor. Again solder one conductor to the (R) terminal and the other conductor and shield to the (L) terminal of the male phono plug; check to be sure that each conductor maintains the proper channel throughout all connections. Solder the shield to the (-) terminal. Assemble the housing over the connections. Seal the holes where the audio connector exits the Pelican case with waterproof glue and allow to dry. Use the ohm meter to test for connectivity between all three contacts of the phono plug; there should be none.

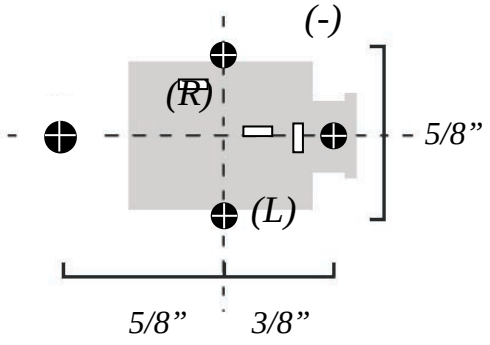
Left: *The outer insulation removed*
Right: *The mylar shield open*



Left: *The stereo phono plug contacts*
Right: *The plug after soldering*



“Zip” style 4” cable ties



Hole pattern in Pelican Case floor

Prepare the windscreen shell

Cut a rectangle of hardware cloth 9.5” x 5.5”. Trim one of the 5.5” edges flat, and leave “tails” on the other 5.5” edge. Trim the 9.5” edges in the same way. Cut a separate square of hardware cloth 3” x 3”. Bend the rectangle into a cylinder 3” in diameter and 5” tall; bend the cylinder so that the resulting circular strands of the mesh are on the outside of the straight strands so that the cage will easily slip onto the holder. Use needle-nosed pliers to bend the wire tails around the mating edge to lock the edges in place. Trim the square piece of hardware cloth so it is roughly a circle 3” in diameter, leaving as many open wire tails as possible at the edge. Place it at the bottom of the cylinder and bend the wire tails to hold it in place. Make sure that no wires protrude outside of the cage so that the windscreen cloth can be slipped over it without snagging.

Cut a rectangle of faux fur 10.5” x 6.5”. With the faux fur on the inside, fold the fabric in half so that the two 6.5” ends are together. Use the sewing machine to make a rectangular pouch by sewing along one 6.5” edge and one 5.25” edge, leaving the other 5.25” edge open. Turn the pouch right-side out and slip it over the wire cage.

Cut a second rectangle of hardware cloth 9” x 2.5”; this will be the windscreen shell holder. Again, leave the tails attached to one of each length edge and trim the other edges so they are flat. Bend the rectangle into a cylinder 3” in diameter; this time bend it so that the resulting circular wires are inside the straight wires. Use the needle-nosed pliers to bend the top row of wire (on the finished edge) inwards, so that the larger cylinder can slip over it. Bend every other wire tail on the unfinished edge 90 degrees toward the center of the shape, leaving every other wire tail straight.

Prepare the microphone

NOTE: If using the PA3 or PA3-IL microphone, each microphone comes with a 6 foot cable and RCA plug adaptor. Some of the following procedure would not be needed, and care will need to be taken to waterproof the connections to the RCA plug adapter.

Drill a 5/32” hole in the center of the plastic plate. Drill 9x 1/16” holes in a ring around the center hole using the windscreen shell as a guide. There is a lot of flexibility in how long the cable to the microphone could be. Longer cable lengths may attenuate high frequencies. 4’ is recommended and lengths up to 8’ should be acceptable. NOTE: The central hole may need to be slightly larger (and then sealed with epoxy waterproof glue) to accommodate feeding a PA3 microphone through the hole.

Cut a length of microphone cable and push 8” of it through the center hole in the plate, with the short tail on the cupped side of the plate. Strip 3/4” of the outer insulation to expose the shield and twist the shield into a pair of leads. Strip back 1/2” of insulation from the (R) and (L) conductors but do not twist into a coherent strand yet. Insulate the back housing of the microphones with a single layer of electrical tape; this will help prevent short circuits to the microphone housing. Begin assembly of the first microphone by inserting the (+) pin of the microphone into either the (R) or (L) conductor, and give the strands a twist. Solder the pin to the wire. Solder the (-) pin of the microphone to one of the shield leads, using the same technique to wrap the wire around the pin. Repeat for the second microphone, using the remaining free conductors. After both microphones are soldered in place, test for connectivity between all connections, and then use a thin layer of waterproof glue to insulate and stabilize the connections. Avoid applying glue to the fabric face of the microphones. NOTE: This step would not be needed for PA3 microphones, but the microphones should be attached to each other and oriented away from each other, and stabilized with glue.

A nearly invisible trace, barely visible on the left pin pictured above, connects the (-) microphone pin to the aluminum housing. Separate the shield lead into a pair of leads and move to the outside of the insulated

The microphones after soldering. The aluminum housing is connected to the (-) pole—take care to prevent short circuits, and be sure to match the microphone polarity with the proper conductor.

When the glue dries, snugly wrap a cable tie around the audio cable 2.5” above the microphone. This will keep the plate from slipping down the cable.

On the opposite end of the audio cable slide the housing for the male audio connector onto the wire. Solder a phono plug to the wire following the same procedure as for the

previously assembled internal connector. NOTE: For the PA3 microphones, at this step you would attach the RCA to 3.5 mm plug connector and waterproof the RCA connections.

Final Assembly

Slide the plastic plate down the microphone wire until it stops on the cable tie. Push the wire tails of the windscreen shell holder through the holes in the plate and bend them down with pliers. Slide the windscreen shell onto the holder; it should fit snugly and stay in place without additional fasteners.

Drill a hole in the back of the Pelican case behind where the 2x2 will rest. Place the lauan back board into the Pelican case behind the audio connector and fix the back board in place by screwing from the back of the Pelican case into the 2x2 board with the deck screw. Tighten the screw so that it seals against the plastic Pelican case.

Plug the audio connector into the top of the recording unit. Strap the recoding unit to the 2x2 board with the Velcro straps. Plug the microphone into the female phone plug on the outside of the Pelican case and power on the recorder. Test the microphone for function. If multiple recorders are deployed it may be worth testing all microphones in a controlled manner to verify that all are similarly sensitive. If the recorders will be deployed in areas with traffic, use one or two locks with at least a ¾" shackle to secure the door closed. Observe that the recorder will function with only two batteries installed if they are installed side-by side within the same battery holder. Using only two batteries will reduce the run time by 50%.

In the photo above, the recorder is shown with a brown microSD to SD adapter lying on the control buttons. This adapter is an option if microSD cards are not available in the capacity desired while SD cards are. In 2010, 32GB microSD cards were available for less than $70 and a 32GB SD card plus adapter cost $95 ($67+$28). We observed that while the adapter made access for card changes easy, occasionally the recorder would not recognize that a new card had been inserted into the adapter and many minutes were spent power-cycling the unit attempting to reboot.

Specifications

Note: Linear PCM is available on the Olympus DM-520 but not on the DM-420 used in this recorder.
Exterior: High impact structural copolymer polypropylene
Exterior Dimensions: 8.12 x 6.56 x 3.56" (20.6 x 16.7 x 9.0cm) (LxWxH)
Microphone Cable Length: Variable
Microphone Cable Shielded: Yes
Microphone Impedence: 2.2 K Ohms
Microphone Directional Properties: Omnidirectional
Microphone Operating Voltage: 2 V
Microphone Sensitivity: - 40 dB +/- 3 dB
Recording Formats: Linear PCM, MP3, WMA
Recording Input Level: [Mic Sense]:[Middle] -60 dBv
Recording Input Impedence: 2.2 kΩ
Recording Power Input: D-cell battery, 2.4 V, 9-11 amps
Recorder Operating Temperature: 0°C - 42°C / 32°F - 107.7° F
Recorder Overall Frequency Response: See table below
Recorder Plug In Power: 0.8 V - 2.5V

Overall frequency response

During recording or playback mode:
Linear PCM format

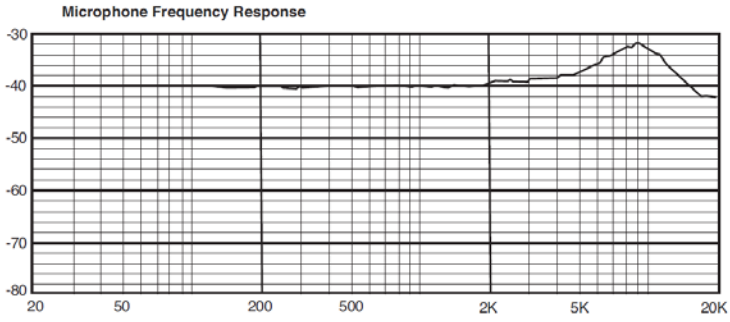
Recording mode	Overall frequency response
48 kHz	40 Hz to 23 kHz
44.1 kHz	40 Hz to 21 kHz

MP3 format

Recording mode	Overall frequency response
320 kbps	40 Hz to 20 kHz
256 kbps	40 Hz to 20 kHz
192 kbps	40 Hz to 19 kHz
128 kbps	40 Hz to 17 kHz

WMA format

Recording mode	Overall frequency response
ST XQ	40 Hz to 19 kHz
ST HQ	40 Hz to 16 kHz
ST SP	40 Hz to 9 kHz
HQ	40 Hz to 13 kHz
SP	40 Hz to 8 kHz
LP	40 Hz to 3 kHz



Maximum recording time per file

Linear PCM format:

48 kHz	3h.
44.1 kHz	3h.20min.

MP3 format:

320kbps	29h.40min.
256kbps	37h.10min.
192kbps	49h.40min.
128kbps	74h.30min.

WMA format:

ST XQ	26h.40min.
ST HQ	26h.40min.
ST SP	53h.40min.
HQ	26h.40min.
SP	53h.40min.
LP	148h.40min.

Maximum Recording Times Based on Storage Media

Linear PCM Format:

Recording Mode	8GB micro SD Card	16GB micro SD Card	32GB micro SD Card
48 kHz	11 h	22 h	44 h
44.1 kHz	12 h	24 h	36 h

MP3 Format:

Recording Mode	8GB micro SD Card	16GB micro SD Card	32GB micro SD Card
320 kbps	54 h	108 h	216 h
256 kbps	68 h	132 h	264 h
192 kbps	90 h	180 h	360 h
128 kbps[1]	136 h	272 h	544 h

WMA Format:

Recording Mode	8GB micro SD Card	16GB micro SD Card	32GB micro SD Card
ST XQ	132 h	264 h	528 h
ST HQ	266 h	532 h	1064 h
ST SP	532 h	1068 h	2136 h
HQ	532 h	1068 h	2136 h
SP	1048 h	2096 h	4192 h
LP	2084 h	4168 h	8336 h

Guide to Battery Life With NiMH Batteries

Recording Mode	2 D-cell Batteries	4 D-cell Batteries[2]
PCM 48kHz	145 h	290 h
MP3 128kbps	159 h	318 h
ST XQ	159 h	318 h
LP	203 h	406 h

[1] The standard recording format in NETN parks is 128 kbps MP3.
[2]Use of 4 D-cell batteries is standard.

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Revision History

Version #	Date	Revised by	Changes	Justification
0.10	Jan 2011	Jonathan Katz	Initial draft: Building an Autonomous Recording Unit Based on the Olympus DM 420 Digital Voice Recorder (Katz, Jan 2011)	
0.11	Feb 2012	Geri Tierney	Reformatted. Added overview and revision history. Editorial changes.	
0.2	June 2012	Jon Katz	Revised procedure to construct a two channel recorder for redundancy & to match microphone power requirements.	
0.21	Oct 2012	Geri Tierney	Editorial and formatting changes.	
1.00	April 2013	Brian Mitchell	Add text describing options (DIY or commercial ARUs), and add option for better microphones and recorders.	Address external review comments

SOP 6 – Deployment and Maintenance of Autonomous Recording Units

Northeast Temperate Network
Version 1.12

Overview

Automated audio recording can be an important data source for long-term phenological research, providing a consistent and objective stream of data at optimal frequency in both accessible and remote locations. This SOP provides specific procedures for the deployment and maintenance of a homemade autonomous recording unit (ARU) that contains an Olympus digital recorder, and the Song Meter recording unit by Wildlife Acoustics, Inc. The Wildlife Acoustics SM1 units depicted in this SOP are no longer available; they have been replaced by the SM2+. Deployment of Olympus and Song Meter ARUs requires slightly different procedures which are described in separate sections of this SOP. The process for downloading and storing audio data collected by these units is also covered by this SOP. This procedure was developed by Corinne Brauer and Jon Katz of the Vermont Cooperative Fish and Wildlife Research Unit at the University of Vermont.

The decision regarding which type of ARU to deploy is up to the individual park. The Song Meters are more convenient, more powerful, and come with a certain amount of technical support, but they also have a higher price tag (about $800 for the unit, batteries, and memory cards). Do-it-yourself ARUs are significantly cheaper and offer a potential learning experience (e.g., for a high school science class), for about a quarter the price.

Deployment of Olympus ARU

1. Pelican case – weatherproofing and protection
2. Battery pack with 4 D Cell batteries – power supply
3. DM-420 Digital Voice Recorder – audio recording device
4. SD Card – data storage
5. Wire leading to external microphone

Figure S6.1. The Olympus ARU.

Figure S6.2. The Olympus DM-420 Recorder. The Olympus DM-620 recorder looks somewhat different.

Before you go into the field

Calibration of Units

If an Olympus ARU will be deployed using a microphone built from component parts (as currently described in the SOP 5 - Building an Autonomous Recording Unit), the microphone must be calibrated to ensure that variation in the fabrication steps (e.g., soldering ability) does not affect performance. Methods are currently being developed for testing and calibrating microphones before deploying them in the field. This will ensure microphone recording quality and uniformity, so that a network of mics is always surveying the same basic area, and that replacing a mic in the event of equipment failure or other operational needs will not impact results.

A preliminary outline for microphone calibration is:

1) Play back low and high frequency test sounds, using a dB meter to ensure a specified volume at 1 m and 10 m.
2) Record the test sounds at those distances, and determine how closely the mic meets the expected signal amplitude and background noise level (to be determined).

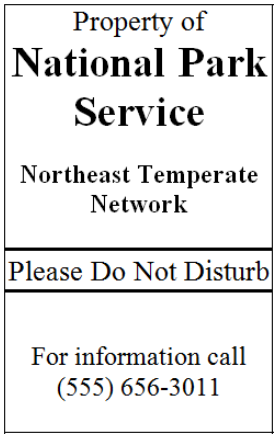
Note any difference and do not use the mic if it does not meet established criteria (a large difference in the recorded dB value and actual value, to be determined). It may be possible to adjust gain settings on the Olympus recorder to calibrate a microphone that does not initially meet the criteria.

Set Date and Time

The time and date used by each unit are set in advance and synchronized among units using the Olympus Sonority Software which is included with the recorder. Install the software if it is not already installed, then connect the Olympus ARU to your computer using the USB cable included with the device. Set your computer time to match the time with the official time at http://www.time.gov/timezone.cgi?Eastern/d/-5/java, and then open Olympus Sonority. In the [Device] menu select [Synchronize Date/Time] and press OK. After disconnecting the recorder from the computer, be sure to set the unit to 24 Hour time by pressing and holding the OK button for two seconds, opening the [Device Menu] and selecting [Time & Date], and then pressing the 'podcast' button once.

Set the Recorder ID

The recorder ID is customized by selecting [Transmit User ID] in the [Device] menu; the first four characters of the user ID will appear as a prefix to each file recorded by the device. Our naming convention is to assign each recorder the four-digit USA-NPN site number corresponding to the site of deployment.



Prepare Units

Camouflage the units using brown and green spray paint before deployment to reduce the visibility of the equipment. Additionally, each unit must have a unique identification number permanently assigned and engraved or otherwise permanently affixed to it. We use the Olympus recorder serial number as this ID number, to assist with documenting potential equipment problems and facilitate deploying units at the same site each

year. Each unit is also labeled with a sticker identifying the organization deploying the units and a request not to tamper with units. See example at right with dummy contact number. The contact phone number is the NETN Program Manager's number (802-457-3368 x37) for network units; or the Park Coordinator's number for park-owned units. It may also help to include the NETN web page for phenology monitoring for people interested in more information: http://science.nature.nps.gov/im/units/netn/monitor/programs/phenology/phenology.cfm.

Test the Unit

A few weeks before taking the unit into the field, insert a memory card and make a test recording. Download the recording and verify that the unit is working as it should and is not recording distorted files or files full of static. This is especially important if a unit has been deployed in a wet or humid environment in the past. While the system is moisture resistant, water can corrupt the microphones and cause them to output nothing but static, or it is possible for the recorder to fail. Rectify any issues before proceeding.

Installation

Supplies and Tools

Olympus ARU with SD or micro SD card and microphones (see SOP 5)
4-6 Plastic cable ties 14" long (cabletiesplus.com item #CP-14-120-B)
2 Packets of desiccant (amazon.com item #B0038N30OY)
4' length of 3/32" vinyl-coated steel cable and a 1/8" cable clamp
Brass lock with ¾" shackle (taylorsecurity.com item# No. 4120KA)
Knife/diagonal pliers to trim cable ties
5/16" socket/nut driver or adjustable wrench to tighten cable clamp

Items listed above without a specified source may be bought at a local hardware store.

Procedure

Figure S6.3. Hanging microphone inside wire mesh and faux-fur.

Select a location with a tree or post that is between 10 cm (4") and 30 cm (12") diameter. The tree should have a sturdy branch 1 to 2 m (4'-7') above the ground from which to hang the microphone. If using a post, the microphone may be hung from a cross-piece (bolted to the vertical post). The microphone is placed 2-3 feet from the recorder box to avoid sound blocking/distortion.

Hang the microphone by wrapping the wire over and around the branch several times, winding the jack towards the trunk of the tree. The microphone may hang any feasible distance from the trunk and should be above deer browse height (approx. 1.8 m). The microphone is inside a windscreen made of wire mesh and faux-fur. The microphone can be visually inspected by holding the base (the plate) as close to the windscreen as possible and gently and slowly rocking the windscreen while pulling it directly off the base. It may help to adjust your grip on the base and the windscreen several times by rotating the base.

Each ARU is enclosed in a weather-proof Pelican case, with a 3.5mm (1/8") mic input jack on the bottom. Pull the case tight against a tree or post by using plastic cable ties. The cable ties pass through the handle on the left side of the case and the steel bar on the right side of the case. Install an upper chain and a lower chain. In addition to the plastic cable ties, install a length of vinyl covered steel rope through the same points, around the tree, and then fasten it with a cable clamp for security.

Figure S6.4. Pelican weatherproof case attached to tree.

Once the ARU is firmly attached to the tree or post, plug the microphone into the jack on the bottom. Arrange the wire so that it falls as close to the trunk as possible, descends below the mic input jack, and then loops once before plugging into the jack. The hanging loop will serve to allow water to drip off the wire before it enters the input jack (as seen above). The Pelican case is watertight, but the input jack is still exposed. Open the case, place two desiccant packs inside, and verify that the unit can power up.

Set Up Continuous Recording

The Olympus ARU does not have the recording flexibility of the Wildlife Acoustics Song Meter; the Olympus is limited to three pre-set recording intervals per day. For this reason, our recommended procedure is to set the Olympus ARUs for continuous recording, with a new audio file produced every 8 hours. We will then subsample this data stream for 5 minutes per hour. Only the subsampled data will be analyzed and archived. In order to facilitate file renaming, preset recording intervals for the Olympus ARU must be a discrete number of hours (i.e., x hours and 0 minutes).

The Olympus DM-420 records MP3 and WMA files with several possible qualities; the MP3 option with the lowest quality (128 kbps) option is recommended regardless of sampling schedule. Use the following procedure to set up and initiate recording:

1) Turn on the recorder by sliding the on button (behind the stop button) down and holding for a few seconds.

2) If not done ahead of time, set the time and date as close as possible to the official US time at http://www.time.gov/timezone.cgi?Eastern/d/-5/java. Set the unit to 24 Hour time while in the time and date menu by pressing the left soft-key (labeled "24H"). Press and release the OK button when done.

3) Record the SD or micro SD card number on the Deployment Datasheet. Each card must be assigned a unique number (which should be written on the card with permanent marker), to assist with linking data to the correct recorder during downloads and trouble-shooting problem cards.

4) Calculate the start and stop times for each 8-hour recording in 24 Hour time on the ARU Deployment Datasheet (Appendix A). Use a start time that is close to the current time, but that provides enough time to program all three recordings. Five minutes should be sufficient.

5) Press and hold the OK button for two seconds to open the main menu. **Scroll** down to the [**Rec Menu**] (microphone icon) and **press OK**.

6) Program the first recording period for a discrete number of hours (i.e., x hours and 0 minutes.

    a. **Highlight** the [**Timer Rec**] option and **press OK**.

    b. **Highlight** [**Preset 1**] and **press OK**.

    c. In [**On/Off**] **select ON**, **press OK**.

    d. Set the [**Day**] to [**Everyday**] and **press OK**.

    e. In [**Time**] set the start time calculated on the deployment datasheet (a few minutes after the current time). Set the stop time calculated on the datasheet (8 hours after the start time, or some other discrete number of hours) and press OK. **Verify that the times match your datasheet**.

    f. Set the [**Rec Mode**] to **MP3**, **128 kbps** and press OK.

    g. In the [**Folder**] option select [**microSD**]. Press OK, then accept the default [**Folder A**] and press OK again. Note that if the Olympus ARU is built according to the current design, you may be using an adapter and an SD card rather than a microSD card; the recorder still refers to this as "microSD".

    h. Confirm that [**Mic Sense**] (microphone sensitivity) is set to [**Middle**] and press OK.

    i. Select [**Finish**] and press OK.

7) Repeat for the second and third recording period for a discrete number of hours, using [**Preset 2**] and [**Preset 3**], and setting each to start at the end of the previous preset's 8 hour recording period and end 8 hours after the start time, so that one starts right as the previous recording ends.

8) Before closing the box confirm that recording begins properly and that the red light turns on.

9) Write the file name for the first recording on your datasheet (this will be displayed on the screen when the unit is recording).

10) Carefully review the ARU Deployment Datasheet, filling in any required data. Review the checklist items, and verify that each item on the checklist has been completed.

****Remember to write all recording start times and SD Card numbers on the datasheet****

A quick way to make sure the ARU is recording to external memory is to confirm that the countdown timer lists at least 73 hours of record time remaining (because this is the maximum file length for files saved to external memory of 4 GB or more using a 128 kbps sample rate). This timer should be visible on the display screen. If it lists less time (such as 34 hours), stop the recording and double check that the file destination is set to the **microSD card**, and then reset all of the timers. However, if you are using a 2 GB SD card or microSD card then it will have the same amount of memory as the internal memory and there will be no difference in the countdown time. The last possibility (an SD card smaller than 2 GB) would mean that the countdown timer should indicate less than 34 hours. The timer may also list a different time remaining if a different file format or quality is selected when setting up the recordings.

For help setting the Olympus Unit to record on a schedule other than 24 hours a day, consult the Olympus Digital Recorder User's Manual provided by the manufacturer.

Deployment of Song Meter SM1 or SM2 ARU

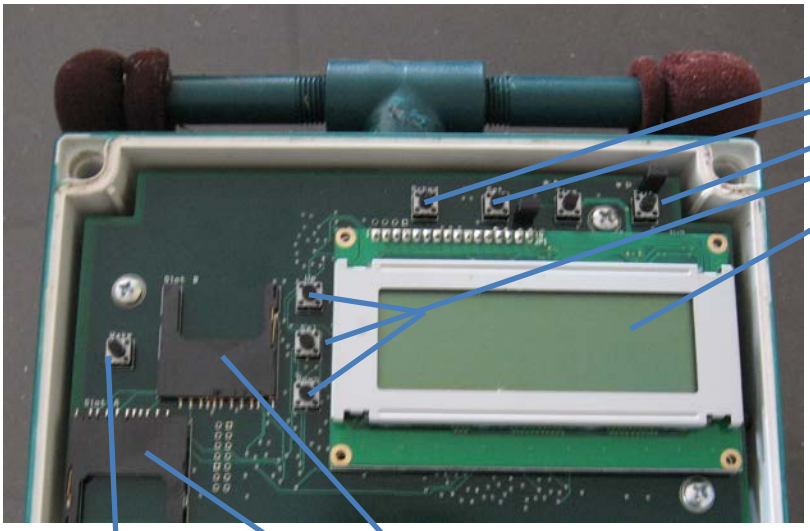


Figure S6.5. The Song Meter SM1 Unit. The currently available SM2 is similar; see user manual for button layout and microphone ports.

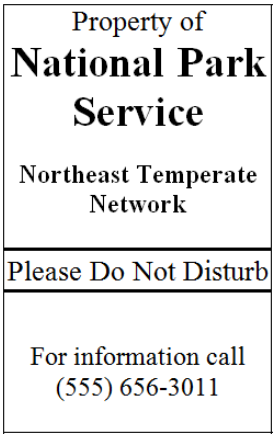
Before you go into the field

Set Date and Time

Manually set the time and date according to the instruction manual as close as possible to the official U.S. time at http://www.time.gov/timezone.cgi?Eastern/d/-5/java. You will need to temporarily install 4 D-cell batteries to set the time, or you can connect an SM2 to an external power supply of 6.5v-25v DC (30v DC can be used if a 1kΩ load resistor is added to the circuit).

Prepare Units

Camouflage the units using brown and green spray paint before deployment to reduce the visibility of the equipment. Additionally, each unit must have a unique identification number permanently assigned and engraved or otherwise permanently affixed to it. We use the Song Meter serial number as this ID number, to assist with documenting potential equipment problems and facilitate deploying units at the same site each year. Each unit is also labeled with a sticker identifying the organization deploying the units and a request not to tamper with units. See example at right with dummy contact number. The contact phone number is the NETN Program Manager's number (802-457-3368 x37) for network units; or the Park Coordinator's number for park-owned units. It may also help to include the NETN web page for phenology monitoring for people interested in more information: http://science.nature.nps.gov/im/units/netn/monitor/programs/phenology/phenology.cfm.



To prepare units for attachment to trees, install four 3" piece of perforated steel tape in a loop to the back of each unit (one at each corner) using 6 x 32 x 3/4" bolts, a washer, and two nuts. The units already have a hole to accommodate the bolts at each corner.

The choice of internal or external power is up to the individual parks. When sites are close to roads, external batteries can be a significant time saver since they reduce the frequency of maintenance visits. However, the weight of these batteries means that D-cells may be better for deployments that are some distance from roads. Keep in mind that, when using rechargeable D-cells, one bad battery can significantly reduce deployment time. Batteries should be individually numbered and if a recorder stops early then all four should be carefully tested. SM1 units have no external power supply port, but for extended deployments it is possible to add one that includes a waterproof connector, reverse polarity protection and a switch voltage regulator (See Appendix D for details). An external power supply cable can be purchased through Wildlife Acoustics, Inc or constructed separately to allow an SM2 or modified SM1 to draw power from a 12V battery. The SM2PWR cable by Wildlife Acoustics dissipates surplus power above 5V as heat, but the switching regulator used in Appendix D will keep that power available and can be as much as 45% more efficient when using a 12V battery source.

To use an external power supply on an SM2, set the power selection jumper to "external". When using an external power supply other than the SM2PWR by Wildlife Acoustics, it is extremely important to make sure it has it has reverse polarity protection or to match polarity of the cable to the battery: The positive (+) terminal and the negative (-) terminal should be marked and matched on both the cable and the battery. The SM2PWR external power supply cable provides reverse polarity protection, but not all other cables do. Failure to connect the external battery properly will likely destroy the voltage regulator, the SM2 motherboard, or both.

The choice of power source and sampling rate depends on several factors, including target taxon, remoteness of recorder, season, and phenophases of interest (see Table S6.1). At a minimum, units should be set to record with lossless compression (i.e., WAC0 format) for 10 minutes at the top of every hour (e.g., 8:00 to 8:10); this schedule incorporates the USGS Terrestrial Wetland

Global Change Research Network (TWGCRN) suggested schedule of 5 min/hour, while allowing for a delay in startup of Song Meter units of 30-60 seconds. Audio files may be subsampled after collection, to yield standardized 5 min/hr samples for analysis. The recommendations in Table S6.1 are intended to be conservative, and may be revised to lower frequencies or shorter durations if research indicates this is warranted. If both birds and anurans are of interest, use the higher sampling rate (24 kHz).

Table S6.1. Recommended sampling rate and schedule by taxon and monitoring purpose.

Taxon	Purpose	Sample Rate	Schedule	Notes
Anurans	Breeding Season	16 kHz	10 min/hour[1]	Omnidirectional mic
Birds	Breeding Season	24 kHz	10 min/hour[1]	Omnidirectional mic
Birds	Migration Season	24 kHz	Continuous, one hour before dusk to one hour after dawn	Directional mic aimed at sky
Bats	Feeding	192 kHz	Continuous, one hour before dusk to one hour after dawn	Ultrasonic omnidirectional mic

[1]Audio files may be subsampled after collection to yield standardized 5 min/hr samples for analysis.

The appropriate sample rate depends on the frequency of the calls being recorded. At a minimum, the sample rate must be twice as high as the vocalization frequency used by the species being recorded, and in practice the sample rate should be somewhat higher (approximately 2.5 times the vocalization frequency is a good rule of thumb). For example if you are recording high-pitched warblers such as the Blackburnian Warbler you will need to record at a minimum sampling rate of 22.05 kHz to capture the high frequency trills above 8 kHz. See Table S6.1 for specific recommendations.

Recording more frequently or at higher sample rates is optional if there is sufficient battery power and memory card space, and enough permanent hard drive storage available for the resulting data. For bats and migrating birds, recording does not need to be continuous if data processing and storage are a significant concern. However, until specific data on detection rates is available, recording for at least 10 minutes per hour between dusk and dawn is recommended.

As Figure S6.6b shows, if recording for only 10 minutes per hour, D-cell batteries may be sufficient to power SM units. However, for continuous recording, an external deep-cell battery is recommended.

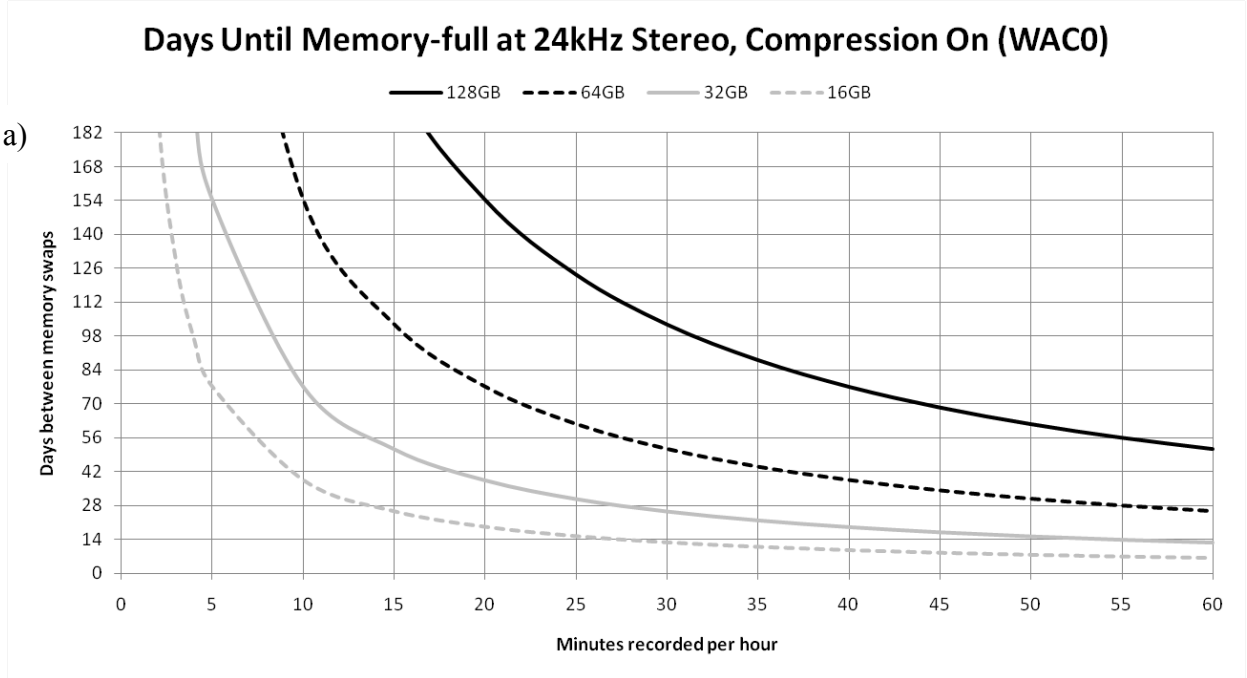
Figure S6.6 illustrates the tradeoffs between sampling rate and power and memory capacity. WAC0 is the lossless compression format offered by Wildlife acoustics in the SM1 and SM2 ARUs. The SM2 has additional lossy compression options available that are described in the user's manual, but are not recommended at this time.

Test The Unit

A few weeks before taking the unit into the field, insert a memory card and make a test recording. Download the recording and verify that the unit is working as it should and is not recording distorted files or files full of static. This is especially important if a unit has been deployed in a wet or humid environment in the past. While the system is moisture resistant,

water can corrupt the microphones and cause them to output nothing but static, or it is possible for the recorder to fail. Rectify any issues before proceeding.

a)



b)

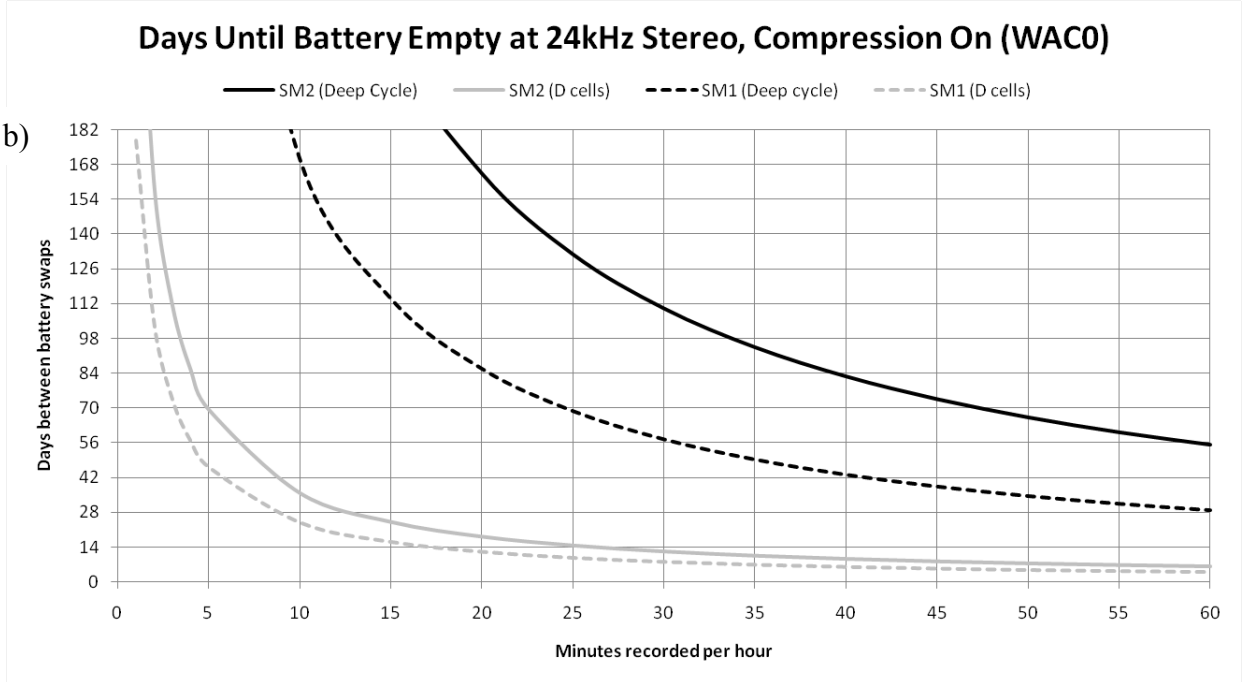


Figure S6.6. Days of SM recording time between maintenance visits for standard 24 kHz monitoring based on size of SD card (a) and battery type (b).

Set Up Recording Schedule

To create a recording schedule, download the Song Meter Configuration Utility from the Wildlife Acoustics website http://www.wildlifeacoustics.com/downloads.php and follow the

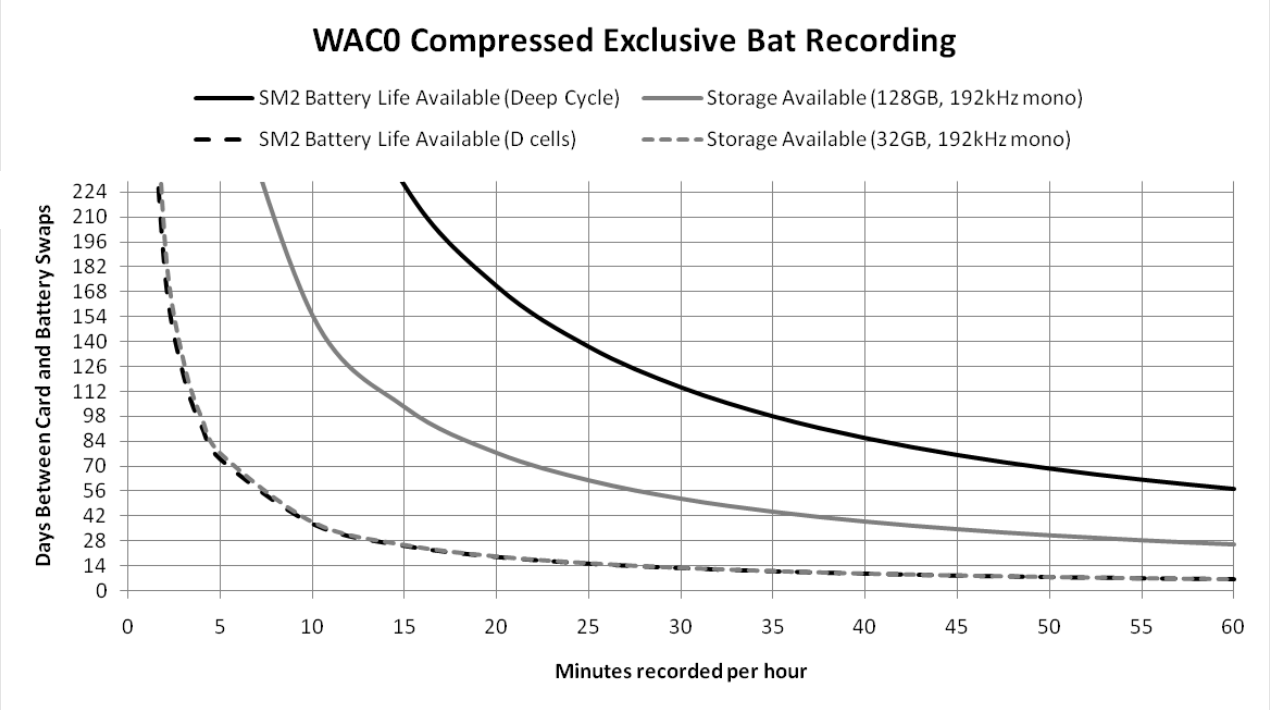
instructions in the user's manual. Depending on the taxon and purpose of recording, you may find the SM2 option for solar tracking valuable.

To monitor bats, use the SM2BAT ultrasonic package from Wildlife Acoustics, which will enable recording rates of up to 192 kHz. Such a high sample rate will require more memory than typically used for monitoring birds or other taxa, although it will consume power at the same rate as the SM1 depicted in the earlier graphs. Figure S6.7 can help when choosing how to power and how much storage to provide for bat and mixed bat-bird recording configurations. The exclusive bat recording schedule assumes no triggering and12 hour bat recording, and the mixed recording schedule assumes no triggering and 12 hour days/nights. Note that analysis of ultrasonic recordings can be done according to the procedures in SOP 7 – Acoustic Template Creation and SOP 8 – Automated Sound Detection and Classification, but that there is good off-the-shelf software available that can classify ultrasonic bat recordings. NETN has a license for SonoBat, and Wildlife Acoustics has recently released bat detection software (Kaleidoscope Pro).

Standard deployment of SM units for phenology monitoring of birds and amphibians in NETN parks uses a sampling rate of 24 kHz. The current recommended sampling schedule is to record 5 minutes at the top of each hour, as per the Terrestrial Wetland Global Change Research Network (TWGCRN) protocol. Detection probabilities are species-specific, but a lower estimate across numerous bird species during a five-minute point count is 0.55. Using this protocol and assuming a detection probability of 0.55 for all species, there is a greater than 95% probability that a species will be recorded vocalizing in at least one of four consecutive recordings. Determination of species-specific detection probabilities using automated methods is in progress.

Save the schedule you create to the highest (root) directory of an SD card and load it into the recorder during setup as described at the bottom of this page. Be sure to either save the schedule to all cards or load the card with the schedule into slot A of the Song Meter.

a)



b)

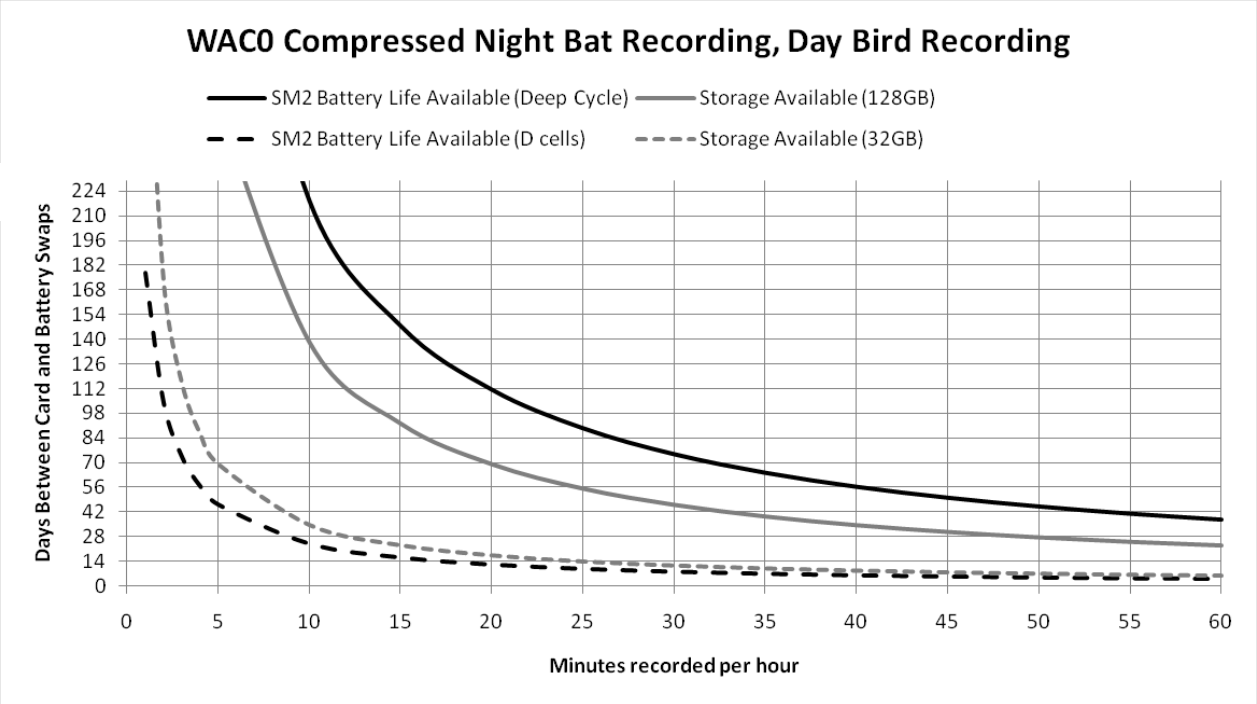


Figure S6.7. Days of SM recording time between maintenance visits for high-frequency bat monitoring (a) and mixed bat and bird monitoring (b).

Installation

Supplies and Equipment

Song Meter recording units with SD cards and microphones
SM2PWR cable (wildlifeacoustics.com) or equivalent if using external power
4-6 Plastic 14” cable ties (cabletiesplus.com item # CP-14-120-B)
Group 24 12V deep cycle battery or 4 D-cell batteries (buy locally)
Group 24 12V battery case (if using external batteries; amazon.com item #B001O0D6QA)
5 ½” and 7” Diameter hose clamps to secure lid of battery box
4’ 3/32 vinyl-coated steel cable and a 1/8" cable clamp
8’ 3/32 cable with swaged loops at ends for securing battery box to a tree
2 Packets of silica desiccant
Knife/diagonal pliers to trim cable ties
Phillips #2 head screwdriver to open and close unit
5/16” socket or nut driver

Items listed above with no specified source can be sought at your local hardware store.

Procedure

Select a location with a tree or post that is between around 10 cm (4”) and 30 cm (12)” in diameter. If possible, avoid placing the unit where it will be in direct sunlight during the hottest part of the day (early afternoon) in summer. If using external power, an ideal tree has an area at the base suitable to place a 12v deep cycle battery in a box. The battery should not tip over and should not be immersed in water if heavy rain causes flooding. Pull the unit tight against a tree or post by two chains of plastic cable ties. The cable ties pass through the metal loops at the corners of the cases and wrap completely around the tree or post. Install a chain of cable ties at the top of the Song Meter unit and a chain of cable ties at the bottom of the unit. If installing on a tree, pass the 4’ vinyl covered steel cable through the lower loops and around the tree, and attach and tighten a cable clamp for security.

If using an external battery, place the battery box at the base of the tree and connect the two hose clamps together at the ends to form a single longer hose clamp. Pass the 8’ cable around the base

of the tree and loop the ends over the hose clamp. Slip the long portion of the hose clamp under the battery box and place the battery in the box. Securely connect the power cable to the battery and the Song Meter, put the lid on the battery box (making sure not to crimp the power cable), and secure the hose clamp over the top of the box to hold it shut.

Open the Song Meter case and place two desiccant packets inside the unit (SM1 only; SM2 units have a moisture absorbing system). Install the SD card with the programmed schedule in slot A and power up the Song Meter by pressing and holding the wake/exit button for two seconds. Press the select button and scroll down to the LOAD SONGMETR.SET FILE, then press select again. Confirm that your schedule has been loaded by pressing schedule and checking the values on the screen, and confirm that the presets have been loaded by pressing Set and checking the sample rate and compression settings. Change the [prefix] for each unit to 8-digit code corresponding to the four-letter NPS acronym corresponding to this park followed by the four digit USA-NPN code corresponding to this site (i.e., ACAD3191 for site 3191 at ACAD), press select until the prefix has been set, and put the unit to sleep by pressing the wake/exit button once.

****Do not leave the monitoring site without completely filling out a ****
****Deployment Datasheet, including the checklist****

Maintenance for Olympus and Song Meter ARUs

Both Olympus and Song Meter units are visited for maintenance and renewal of batteries and SD cards periodically. A full complement of 4 D-cell batteries will power the Olympus ARU for approximately 318 hours (13 days) of continuous recording in the recommended format (128 kbps MP3), using a 32 GB micro SD card. Alternatively, a 16 GB micro SD card will be filled after 272 hours (11 days). The Olympus units are visited every 7-13 days, depending upon observer schedule and size of micro SD card installed.

Wildlife Acoustics SM units are visited weekly to monthly, based on the sampling schedule, SD card and battery used. An SM1 recording in stereo at a 24 kHz sample rate with compression on (i.e., WAC0), two 32 GB cards and an external deep cycle battery should be able to run continuously for 21 days or for 5 minutes per hour for about 210 days (7 months) without needing maintenance. Make sure to load the empty memory card(s) with the recording schedule prior to heading into the field. An SM unit running on D-cell batteries will need much more frequent maintenance. See the Figure S6.6 and Appendix S6.B to determine maintenance intervals for alternative recording schedules.

The Maintenance Log (Appendix S6.C) should be filled out at each visit, in addition to an ARU Deployment Datasheet (Appendix S6.A). Upon arrival at the deployment site, open the Song Meter. If it is supposed to be recording during your visit, you can verify that it is recording by checking the LCD screen and observing the elapsed time. If you are using a daily schedule and the LCD screen is not illuminated, you can press the Wake button and observe how much of the memory is full. Pressing Exit will report the next scheduled event. Be aware that if using an advanced schedule (coded line by line) on an SM1, wake/sleep cycling the unit will restart the schedule at line 1. If you are not going to replace the SD card, and your schedule is sensitive to sunrise/sunset times or other small time shifts, you should wait for the next scheduled event for

the unit to self-wake and report the card volumes. An SM2 will wake/sleep without losing its place in the schedule. Change the memory card and batteries while the unit is sleeping, and then follow the procedures on the previous page for installing the SD cards and verifying the schedule and settings.

The desiccant packet is checked regularly, and replaced with a fresh packet anytime it appears swollen.

****Remember to fill out the Deployment Datasheet completely****

Downloading Audio Data from Olympus and Song Meter ARUs

SD Cards

Both the Song Meter and Olympus recording units (with an SD adapter) store the audio data they record on standard sized SD (Secure Digital) cards (SDHC) that can be purchased online or at most electronics stores. The Olympus recorder can also use a micro SD card. SD card are available in sizes up to 32 GB, and micro SD cards are available in sizes up to 16 GB. The Olympus recorder uses a single card, the Song Meter SM1 can use one or two cards, and the SM2 can use up to four cards. The choice of memory capacity will depend on the project budget, recording sample rate and schedule, and expected maintenance schedule. In general, it helps to purchase the largest capacity cards that the project budget can afford. The price for a 16 GB SD card is around $25 currently, while the price for a 32 GB card is around $50 currently (micro SD cards are more expensive). Prices are expected to drop in the future, following the trend of data storage becoming cheaper over time.

Download

Once collected from the field, the audio files on SD cards are downloaded onto an office computer or external hard drive using a USB-based SD card reader. The card is plugged into the reader and the reader is then plugged into the USB port of a computer and the device should then appear on the computer. Files can then be moved to the location directed by your data management plan. The date a given audio file was recorded should be shown in the properties of the file under date modified, but keep in mind that if any manipulation is done to the file this information may be lost.

If this unit has been properly set up to assign the correct four digit prefix for the file names, they will appear for the Olympus ARU files as the prefix followed by a string of unique numbers that increase from one file to the next in the order they were recorded. For example 31910001 would be a file recorded at site 3191. The next file recorded will be named 3191002. For the Song Meter ARUs, the file names will appear as the prefix followed by a string of numbers which reflect the date and time of the recording, i.e. PARKXXXX_YYYYMMDD_HHMMSS. For example, ACAD3191_20100528_001856 would be a file commenced at ACAD site 3191 on 28 May 2010 at 12:18:56 AM. If the unit was not set up to add a unique prefix to the file name (as explained in the installation procedures above) then the proper file names must be assigned now to reflect the park, site and order of recording or date/time, as described here.

Make sure to create duplicate backups of all recordings (for example, download the files to a computer hard drive or external hard drive, and back the files up to a separate external hard drive

as well). In addition, a copy of the recording schedule file for the Song Meter ARU should be stored with the data collected by that ARU. The naming convention for these files is PARKXXXX_YYYYMMDD.SET. For example, ACAD3191_20100527.SET is the settings file that was used at the ACAD site 3191, starting on 27 May 2010. A new version should be saved whenever the deployment settings are changed. Deployment settings should never be changed within a monitoring season, and should only be changed with careful consideration regarding the compatibility of a new schedule with existing data.

Depending on the speed of the computer being used, download may take a substantial amount of time (up to 30 minutes for a 32 GB card). Keep this in mind if downloading will be done in the field, which might be the case if you do not have enough SD cards to switch all full ones for empty ones in one visit.

Once the audio data has been downloaded, files on the card are erased in order to reuse the cards. Occasionally a card will malfunction and fail to record data properly. In this case, it may help to reformat the card upon download. The Olympus unit has a card reformatting function to reformat in the field (for details see the Olympus instruction manual). The files containing the recording schedule for Song Meter units can be left on the card if you wish to use the same schedule, or it can be erased and replaced with a new schedule. Be careful about reusing schedules that contain specific start and stop dates (rather than those set to record a certain amount per day) as they will not be reusable.

File Types

The files from the Olympus units are recorded in MP3 format, while the files from the Song Meter are WAC0 format (developed specifically by Wildlife Acoustics). The MP3 is a lossy compressed file format, meaning that some audio data is thrown out for the sake of smaller files sizes when compression is performed. WAC0 is a lossless compressed file format and does not lose any information in the process of compression but results in a larger file size than the MP3 format. Different audio software may require different formats in order to play, view, and manipulate audio data, so it may be necessary to convert these files into different formats.

Converting Files

Olympus MP3 files can be converted to other formats using free downloadable audio software. One option is called Audacity which can be downloaded at http://audacity.sourceforge.net/ and another option is RealPlayer which can be downloaded at http://www.real.com/

Song Meter WAC0 files can be converted to WAV files using free Kaleidoscope software available for download on the Wildlife Acoustics website at http://www.wildlifeacoustics.com/support/download-software
The files can then be converted to forms other than WAV if necessary using the same audio tools listed above for the Olympus unit.

Revision History

Version #	Date	Revised by	Changes	Justification
0.10	March 2011	Corinne Brauer, Jon Katz	Original Version of Deployment and Maintenance of Autonomous Recording Units (Brauer and Katz, September 2011)	
1.00	March 2012	Geri Tierney, Jon Katz	Reformatted. Made specific recommendations for standard NETN monitoring. Added revision history. Editorial changes.	
1.11	Dec 2012	Geri Tierney	Reformatted. Revised unit and file naming. Accepted time format as current US time (for Sonority). Specified Olympus ARU should record in whole hour units to facilitate file renaming. Adjusted recording time to include SM startup time.	
1.12	April 2013	Brian Mitchell Geri Tierney	Clarified that Olympus and Song Meter require separate deployment procedures. Added info about tradeoffs between Olympus and Song Meter units. Added section on camouflaging/labeling units to the Song Meter deployment section. ARU testing should be a few weeks prior to deployment, in case units need repair. Other minor changes to address comments..Editorial changes.	External review
1.13	July 2013	Ed Sharron	Editorial edits to bring into line with other NETN protocols. Updated Wildlife Acoustics website and software options.	

Appendix S6.A. ARU Deployment Datasheet

Equipment (Olympus ARU):
Writing utensil
Empty SD or micro SD card
Spare Olympus ARU windscreen
Key to Olympus ARU locks (if used)
4 D-cell batteries
Packets of silica desiccant

Equipment (Song Meter):
Writing utensil
Empty SD card(s)
Spare Song Meter windscreen
Phillips #2 screwdriver to open and close units
Charged 12V *or* 4 D-cell batteries
5/16" socket or nut driver for 12V battery case
Packets of silica desiccant

Date:_____ Location/Park: _____ Site #_____ Serial # _____
Lat:_____ Long: _____

Circle one: Initial Deployment *or* Maintenance Deployment

Circle one: Olympus ARU *or* Song Meter SM1 *or* Song Meter SM2

For Olympus ARU*:

Preset 1 Start / 3 Stop: _____

Preset 2 Start / 1 Stop: _____

Preset 3 Start / 2 Stop: _____

For Song Meter:

Recording Start Time*: _____

Schedule File: _____

First file name: _____

	New/Empty		Used/Full[1]	
	Card ID	GB (circle one)	Card ID	GB (circle one)
Olympus / SM Slot A		4 8 16 32		4 8 16 32
SM Slot B		4 8 16 32		4 8 16 32
SM Slot C (SM2 only)		4 8 16 32		4 8 16 32
SM Slot D (SM2 only)		4 8 16 32		4 8 16 32

[1] For Maintenance Deployments only

Notes (e.g., any signs of disturbance or recorder problems):

Checklist
___ Take out the old 12V or D-cell batteries and replace with a fresh 12V or D-cell batteries
___ Take out the full SD cards and replace with empty SD cards
___ Record SD card numbers in datasheet
___ Reset the recorder for a new 24 hour (or other desired) recording schedule
___ Record start time* for recording schedule
___ Check the packet of desiccant and ___ replace if necessary
___ Check the unit and cables over for any damage or needed adjustments
___ Remember to shut all units and battery cases

Appendix S6.B. Unit Specifications

Olympus Unit Specifications

Exterior: High impact structural copolymer polypropylene
Exterior Dimensions: 8.12 x 6.56 x 3.56" (20.6 x 16.7 x 9.0cm) (LxWxH)
Microphone Cable Length: Variable
Microphone Cable Shielded: Yes
Microphone Impedence: 2.2 K Ohms
Microphone Directional Properties: Omnidirectional
Microphone Operating Voltage: 2 V
Microphone Sensitivity: - 40 dB +/- 3 dB
Recording Formats: Linear PCM, MP3, WMA
Recording Input Level: [Mic Sense]:[Middle] -60 dBv
Recording Input Impedence: 2.2 kΩ
Recording Power Input: D-cell battery, 2.4 V, 9-11 amps
Recorder Operating Temperature: 0°C - 42°C / 32°F - 107.7° F
Recorder Overall Frequency Response: See table below
Recorder Plug In Power: 0.8 V - 2.5V

Maximum Recording Times Based on Storage Media

MP3 Format:

Recording Mode	8GB micro SD Card	16GB micro SD Card	32GB micro SD Card
320 kbps	54 h	108 h	216 h
256 kbps	68 h	132 h	264 h
192 kbps	90 h	180 h	360 h
128 kbps	136 h	272 h	544 h

WMA Format:

Recording Mode	8GB micro SD Card	16GB micro SD Card	32GB micro SD Card
ST XQ	132 h	264 h	528 h
ST HQ	266 h	532 h	1064 h
ST SP	532 h	1068 h	2136 h
HQ	532 h	1068 h	2136 h
SP	1048 h	2096 h	4192 h
LP	2084 h	4168 h	8336 h

Song Meter Unit Specifications

Physical Specifications

• Dimensions: 8.0” X 8.0” X 2.5”
• Weight: 2.0 pounds without batteries
• Enclosure: NEMA Type 1,4,4X and 6 (weatherproof, vented). A self-regenerating humidity control device such as Zorb-It is required to prevent condensation in some conditions.

Appendix S6.B. Unit Specifications (continued)

• Operating Temp.: -4ºF to +185ºF -20ºC to +85ºC (Inside the enclosure - avoid exposure to direct sunlight in hot environments. Also note that operating range of the batteries used may be narrower).

Audio Specifications

• Channels:2
• Interface: 3-pin waterproof connector (ground, signal, 3.3V supply)
• Bias power: 2.5V 2.2K ohm, jumper enabled per channel
• High-pass filter: 2-pole butterworth, jumper selectable per channel at 2, 180 or 1,000Hz
• Pre-amplifier: 2-stage, jumper selectable per channel, at +0, +12, +24, +36, +48, or +60dB gain. For sample rates <= 48kHz, third-stage digitally-configurable +0-+12dB in 1.5dB steps
• Noise: -115dBV equivalent input noise
• ADC: 1V rms full-scale 16-bit, 90dB SNR
• Sample rates: 4, 8, 16, 22.05, 24, 32, 44.01 and 48kHz standard; 192kHz and 384kHz available with SM2BAT192x2 and SM2BAT384 dauther cards.
• Digital format: 16-bit PCB (.wav) or proprietary lossless and lossy compression formats (.wac).
• Headphones: 3.5mm stereo jack
• Filtering and triggering: Configurable digital high-pass and low-pass filters at sample rate divided by 3, 4, 6, 8, 12, 16, 24, 32, 48 and 96. Adaptable trigger with configurable threshold above background 1-88dB, absolute trigger with configurable threshold -1 - -88dB full scale, inactivity time for trigger off 0.1 - 9.9 seconds.

Sensors

• Channels: 2
• ADC: 10-bit at 3.3V reference (3.2millivolt resolution)
• Parameters available for precise calibration
• Internal temperature sensor accurate to within ±2ºC at 0ºC.
• External sensor port with 3-pin waterproof connector (ground, signal, 3.3V supply)

Storage

• 4 SD/SDHC/SDIO flash card slots (Class 4 or greater)
• 128GB total capacity with 4x32GB cards available today, more as higher capacity cards become available
• Compression increases effective capacity by 60-70% typically

Power

• 4-10VDC main power (internal 4 D-size batteries or external weatherproof connector)
• 6-20VDC through external power adapter for 6 or 12V solar power systems
• < 1mA when idle between scheduled recordings
• *The following estimates can vary 10mA depending on flash cards used:*
• 55-65mA when recording uncompressed up to 48kHz (except 32kHz), compressed up to 16kHz mono, and band triggered up to 8khz mono.

Appendix S6.B. Unit Specifications (continued)

• 70-75mA when recording compressed up to 48kHz (except 32kHz), and band triggered up to 24kHz mono.
• 80-90mA when recording 32kHz and up to 48kHz compressed, and band triggered up to 44.1kHz mono.
• 90-100mA when recording band triggered up to 48kHz mono.
• 110mA when recording band triggered up to 48kHz stereo.
• Separate power for time-of-day clock uses 2 AA-size batteries, < 0.1milliamps (2-3 year service life)

SMX-II Microphones

• Enclosure: NEMA 4X weatherproof
• Sensitivity: -36±4dB (0dB=1V/pa@1KHz)
• Frequency response: flat 20Hz - 20,000Hz
• Signal-to-Noise Ratio: > 62dB
• Directionality: Omnidirectional

Memory Capabilities
Recording Times (in Hours)
Mono (1 channel)

	48,000	**44,100**	**32,000**	**24,000**	**22,050**	**16,000**	**8,000**	**4,000**
2GB	5.8	6.3	8.7	11.6	12.6	17.4	34.7	69.4
4GB	11.6	12.6	17.4	23.1	25.2	34.7	69.4	138.9
8GB	23.1	25.2	34.7	46.3	50.4	69.4	138.9	277.8
16GB	46.3	50.4	69.4	92.6	100.8	138.9	277.8	555.6
32GB	92.6	100.8	138.9	185.2	201.6	277.8	555.6	1111.1
64GB	185.2	201.6	277.8	370.4	403.1	555.6	1111.1	2222.2
128GB	370.4	403.1	555.6	740.7	806.2	1111.1	2222.2	4444.4

Stereo (2 channels)

	48,000	**44,100**	**32,000**	**24,000**	**22,050**	**16,000**	**8,000**	**4,000**
2GB	2.9	3.1	4.3	5.8	6.3	8.7	17.4	34.7
4GB	5.8	6.3	8.7	11.6	12.6	17.4	34.7	69.4
8GB	11.6	12.6	17.4	23.1	25.2	34.7	69.4	138.9
16GB	23.1	25.2	34.7	46.3	50.4	69.4	138.9	277.8
32GB	46.3	50.4	69.4	92.6	100.8	138.9	277.8	555.6
64GB	92.6	100.8	138.9	185.2	201.6	277.8	555.6	1111.1
128GB								

Appendix S6.C. Maintenance Log

Unit #: _____ Date Purchased or Produced: _____
Unit Type (Circle): Olympus DM-420 Song Meter SM1 Song Meter SM2
Recorder SN: _____ Mic ID (R):_____ Mic ID (L): _____
Additional Sensors (SM2 Only): _____
Record deployment details and troubleshooting information below; specifically note dates when any mics or sensors were changed for this unit, as well as memory card failures.

Date	Activity[1]	Notes

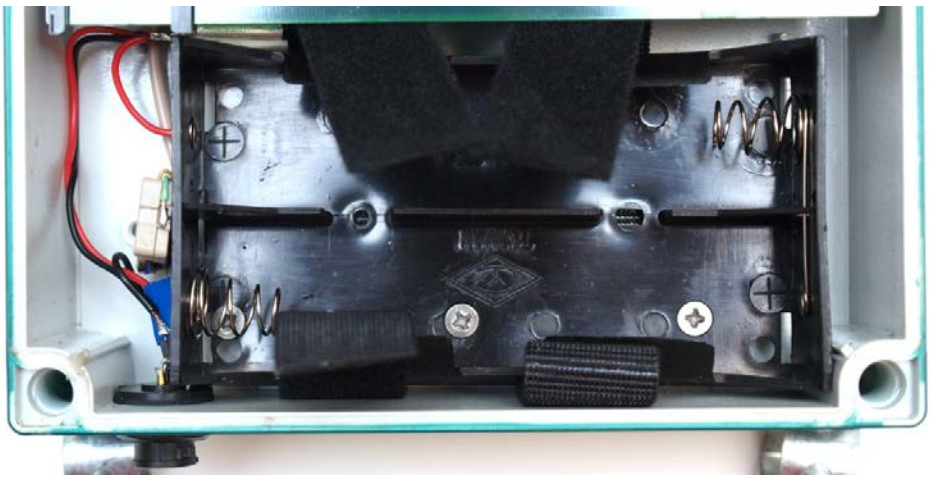
[1] (T)esting or trouble-shooting, (D)eployment, (M)aintenance, (R)emoval

Appendix S6.D. Building an External Power Cable for an SM1 or SM2 Recording Unit

Materials for an external power cable, reverse polarity protection, and voltage regulator:
6’ 18 gauge or thicker insulated, stranded, dual conductor wire
2 5/16” crimp-on electrical “eye” terminals
Conxall waterproof plug end (digikey.com item # SC1263-ND)
Conxall waterproof jack (digikey.com item # SC1272-ND)
5V Switching voltage regulator (dimensionengineering.com item # DE-SW050)
1A Bridge rectifier diode (digikey.com item # 641-1211-1-ND)
Perforated single sided prototype board (digikey.com item # V2018-ND)
18 gauge insulated stranded hook-up wire: green, red, and black insulation colors
1” length of ¾” wide double-sided mounting tape
¾” stepped drill bit
Phillips #2 screwdriver
Drill
Fine-point craft knife
Wire cutter
Wire stripper
Soldering iron & solder
Ohm meter/volt meter

Make the cable:
Strip ½” of insulation from the same end of both dual conductor wires, and strip ¼” of insulation from the other end. Crimp the eye terminals to the ends with ½” of cable visible. Slide the locking collar and rubber seal over the other end of the cable, solder the cable to the internal contacts of the plug, and assemble the plug.

Install an external power port in an SM1:
Unscrew the internal battery holder and move to the side. Drill a ¾” hole in the floor of the case of the SM1 to the left of where the battery holder sits; make sure that it clears the mounting hole in the case and the battery holder.

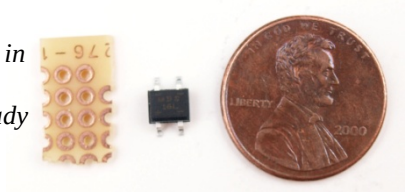


Remove the internal battery holder (remove the three screws visible along the lower edge in the image at right) and drill a hole with the stepped bit. Be sure to leave clearance for the lip of the connector and the battery holder!

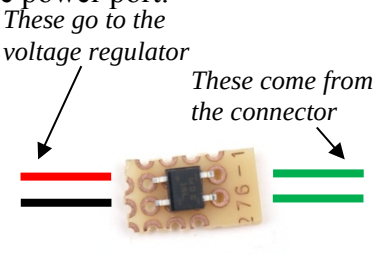
Appendix S6.D. Building an External Power Cable for an SM1 or SM2 Recording Unit (continued)

Add reverse polarity protection to an SM1 or SM2:
Cut a section of the perforated circuit board so that you have at least a 2x4 hole pattern to work on. Cut two pieces of green hookup wire 3" long and strip 1/8" of insulation from all ends. Solder one end of each wire side-by-side in adjacent holes at one end of the perforated board. Cut a 4" length of red hookup wire, a 4" length of black hookup wire, and a 3" length of black hookup wire. At the opposite end of the perforated board enlarge the hole that will correspond to the negative (-) output from the rectifier diode (this should be marked on the top of the diode); the hole should be large enough to fit two wires through. Pass the end of the black 4" and 3" section of wire through and solder to the board. Solder the red 4" piece through the board next to it. The board should now have two green wires at one end and a red wire and a black wire at the other end, and the two ends should be separated by a 2x2 square of holes. Place the bridge rectifier on top of the soldered wires so that the 4 pins mate up with the 4 wires with no potential to short circuit. Be sure that the two pins marked (~) line up with the green wires, the positive pin (+) lines up with the red wire, and the negative pin (-) lines up with the black wire. Solder the pins to the wires. Solder a green wire to each pin of the external power port. If working on an SM2 you will need to first desolder the existing wires attached to the power port.

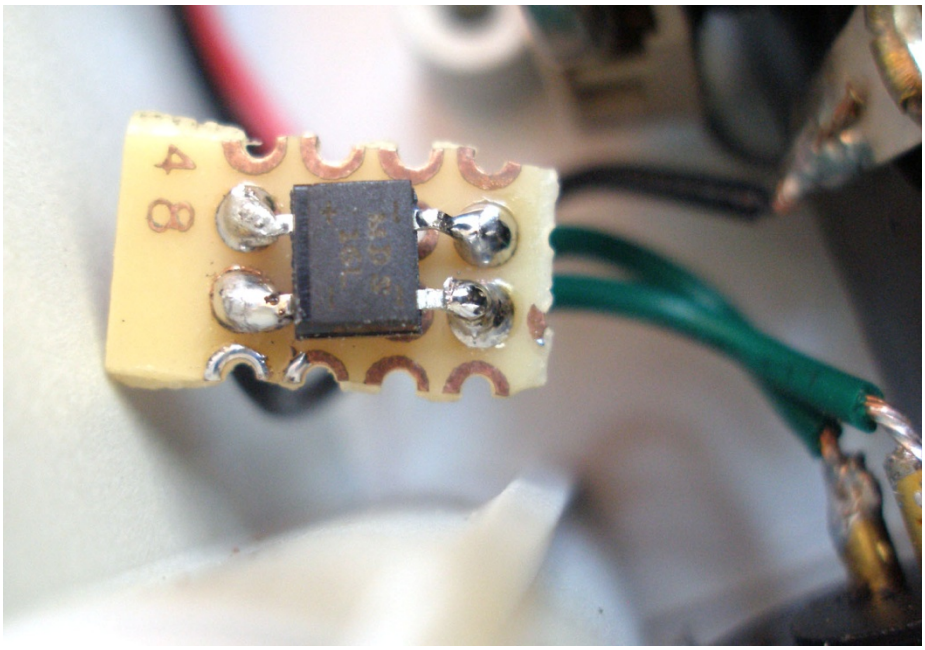
2x4 hole pattern in board. This is a small diode, steady hands help!



Solder the wires to the board before attaching the diode. Be sure the green go to the (~) terminals, red to (+), and black to (-).



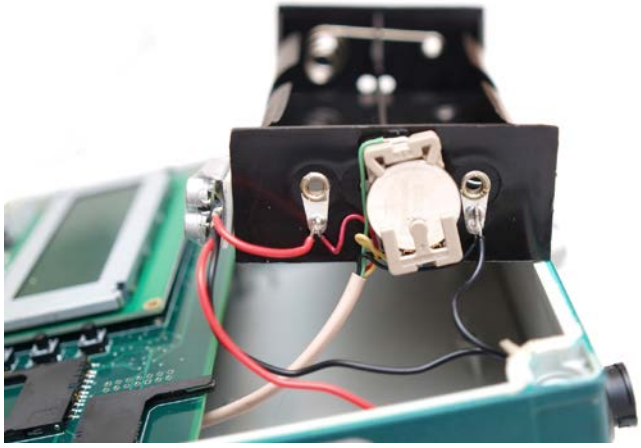
When installed it should look something like this.

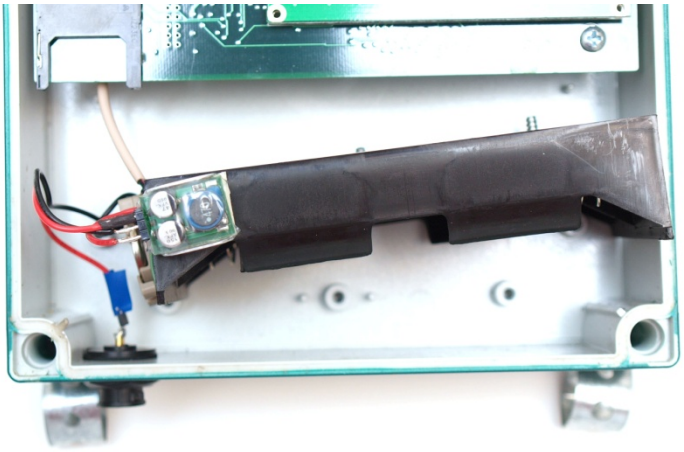


Appendix S6.D. Building an External Power Cable for an SM1 or SM2 Recording Unit (continued)

Add the voltage regulator to an SM1 or SM2:
SM1: Solder the 4" black wire from the bridge rectifier to the GND (center) pin of the switching voltage regulator. Solder the red wire from the bridge rectifier to the V_{in} pin of the voltage regulator. Solder the 3" black wire from the bridge rectifier to the negative (-) terminal of the battery holder. Cut a 3" length of red wire and strip ¼" of insulation from each end. Solder one end to the V_{out} pin of the voltage regulator and the other end to the positive (+) terminal of the battery holder. Test for short circuits, and test that the bridge rectifier channels input power to the positive pole only. When testing shows satisfactory performance, use the mounting tape to stick the voltage regulator to the side of the battery holder and replace the battery holder back in the case and screw it down.

SM2: Similar to instructions above for SM1, but rather than connecting the voltage regulator to the battery holder, instead make all connections to the appropriate external power in wires. Note that the pictures below are of an SM1.





SOP 7 – Acoustic Template Creation

Northeast Temperate Network
Version 1.01

Introduction

There are a variety of tools available for automatic detection of species on audio recordings. Among these, perhaps the best known is the Wildlife Acoustics Song Scope platform, which uses a "Hidden Markov Model" algorithm with carefully developed recognizers to detect species on field recordings. After much consideration, we decided not to use Song Scope for the following reasons:

1) Song Scope is a "black box", and it is not clear exactly what the recognition algorithm does.
2) Song Scope recognizers can only be built by many rounds of trial and error, and tweaking numerous parameters. Building recognizers is an art, not a science.
3) Song Scope is not suitable for long term monitoring since regular software updates alter the recognition algorithm and require complete reanalysis of all prior data to ensure consistency.
4) Song Scope is expensive, especially for a program intended to run in a distributed fashion with many people running analyses.

NETN staff and cooperators decided that the best approach would be to use simple algorithms (spectral cross correlation and binary point matching). While the implementation is perhaps not as user-friendly as commercial software, the algorithms are easy to explain and visualize, have many fewer parameters to worry about when trying to build templates, and have been shown to be accurate for identifying many species. The approach is implemented on a free, widely used platform (R), and because the basic algorithms are not being changed over time, old data does not need to be reanalyzed unless a new species template is developed. The R platform and package we have developed definitely has a learning curve, but so does the process of building recognizers in Song Scope.

This SOP provides specific instructions for creating templates to use in automatic sound detection. It was developed by Jon Katz for use by the NPS Northeast Temperate Network Phenology Monitoring Program. SOP 8 – Automated Sound Detection and Classification describes the overall process of managing audio files and analyzing them with existing species-specific templates and the R package (monitoR) that has been developed for automated sound recognition.

Software Programs Used

Sound detection is performed within R, "a freely available language and environment for statistical computing and graphics" which can be downloaded from the Comprehensive R Archive Network (*http://cran.r-project.org/*).
Before using R for spectrogram cross correlation or binary point matching, add these packages[1] to your R library:

1. tuneR
2. plyr
3. RODBC (for connecting R to a database)

See Appendix S8.C in SOP 8 - Automated Sound Detection and Classification for instructions on downloading R and selected packages. Audacity is a free audio editing application which provides a useful tool for viewing sound files (*audacity.sourceforge.net*). Audacity works on MacOS, Windows, and Linux operating systems, and can be installed as a zip file (which is helpful if you are on a computer with restricted permissions). Before working in Audacity, set these default preferences. In the Edit menu choose "Preferences", select "Spectrograms" from the list on the left, and check the box to "Show the spectrum using grayscale colors". Set the default window size to 1024. Close the preference panel. Set Audacity to open files in spectrogram view by clicking "Tracks" in the list on the left and setting the Default View Mode to "Spectrogram". Click OK .

A WAV file player is needed during template construction to verify that results sent from R are the target sound of interest. Use a pre-installed player (e.g., Windows Media Player in Windows, Quicktime in MacOS, or Rhythmbox in Linux) or use a dedicated cross-platform player that can be opened via the command line (through R) such as wv_player.exe or SoX. Note that if you choose to use Windows Media player the application name you will pass to R is wmplayer.exe, while Ubuntu's Rhythmbox is rhythmbox. wv_player can be downloaded at (*http://download.cnet.com/WV-Player-formerly-Wav-Player/3000-2139_4-10472299.html*), and SoX at (http://*sox.sourceforge.net*).

[1] A package is a set of functions that runs in R.

Terminology

Bandpass filter: An audio filter that trims frequency data from above and below the frequency band that is allowed to "pass" through. In the digital implementation here, we specify a minimum and maximum frequency that we want to pass through and all frequencies below the minimum and above the maximum are discarded.

Binary point matching: A method for sound detection in which the acoustic template is converted to a matrix of "on" and "off" cells. The mean amplitude (in decibels) of the corresponding "on" points at each time interval in the survey is compared to the mean amplitude of the corresponding "off" points. The user specifies a minimum acceptable difference between the two values to limit the results, and local maximum-difference values above the minimum value identify events.

MP3: A "lossy" compression file format engineered to preserve the most audible human speech frequencies. The compression process has a number of components, and the degree of information loss is determined by how much information must be trimmed to meet the target file size per second (minimum size is 128kbps). MP3 files are low-pass filtered above the threshold of human hearing, and occasionally low amplitude frequency data are discarded if they occur simultaneously with high amplitude frequencies. MP3 files save considerable storage space versus uncompressed files, but obligatory decompression time can be substantial.

Spectrogram cross correlation: A method for seeking a known template in a survey consisting of unknown songs. The correlation of amplitude values in the FFT template matrix to a matrix in the survey is measured using the Pearson method. The survey matrix then shifts one time bin and the correlation to the template is measured again. The user specifies a minimum Pearson score, and local maximum scores identify events.

Survey: A recording that will be searched for the template. Must be a WAV or MP3 file, and must be longer than the template.

Template: A recorded song example which will provide the "search image" for the computer. Must be a WAV or MP3 file. A template may differ from a simple song clip by retaining bandpass filter values and score cutoff values.

WAC: The Wildlife Acoustics proprietary compression format. Use of this format is restricted to Wildlife Acoustic's Song Meter recording units. These units are the data collection standard due to their flexible timed recording, high storage capacity, ultrasonic recording options, data-logging and GPS integration, and weatherproofing. WAC files must be converted to WAV files for use in the R environment using Wildlife Acoustics conversion software.

WAV: An uncompressed linear PCM audio file format owned by Microsoft that is in widespread use sufficient to be considered cross-platform. As a result WAV files are playable on nearly all devices.

Create an initial template

To analyze your acoustic files, you will need to create some templates. A template is built from a recorded song example, and provides the "search image" for the computer. The recorded song must be a wav or mp3 file, usually one that is clipped from a survey file or one that is recorded using a directional microphone. There is a distinction between the recording and the template; unlike the song clip, the template will contain only the portions of the song clip to be used for analysis and it will contain information about the sampling rate, the FFT parameters, and the score cutoff that should be used with it. Template files have extensions bt or ct, and the song clips they are built from have extensions wav or mp3. Templates can be made once, saved, and used many times. Templates are sampling-rate and FFT parameter-specific; for example, if you are using some mp3 recorders that sample at 44.1kHz and some Song Meters that sample at 24kHz it is necessary to either make a template for each sampling rate or to downsample the 44.1kHz files to 24kHz. Similarly a template made from an FFT window length of 512 and a hanning window function can only be used at that FFT length.

If you are using a database, each template is assigned an ID number, and information about the template – and the template file itself - is stored in tblTemplate, including:

1. Species – the species that was recorded
2. Person – the person who recorded the template
3. Location – the location in which the template was recorded
4. Template name—each template must have a unique name
5. Recording date – the date in which the template was recorded
6. Recording equipment – the equipment used to record the template.
7. Original file name—the song clip the template was made from
8. Sample rate—the sampling rate the song clip was recorded at
9. FFT window length—the window length
10. FFT window name—the window function applied to each window
11. Template data – this is the actual template itself
12. Template type—either binary (BIN) or correlation (COR)

The work-flow for template creation is as follows:

- Locate a song that will be used to create template; use monitoR to seek a song example to clip.
- Clip the relevant portion of the recording, and save the clip in the Template directory. Save as mp3 or wav format.
- Use the makeBinTemplate or makeCorTemplate functions to build the template.
- Use the makeBinTemplateL or makeCorTemplateL functions to add a score cutoff and create a template list
- Upload the template list to tblTemplate of the database or save it to the Template directory.

The first step in choosing a song template is to find an example of a target song. Ideally it would be a superb example with high signal:noise and no interference, but if the only example you can find is low quality, you can still use it to help you find additional, better examples as you acquire more recordings. An easy way to find a first template is to order one from the Macaulay Library (*macaulaylibrary.org*). Alternatively, you can use one of your recordings. Let's assume you have

a long wav file called MABI02_A_052710.wav on your C drive and you'd like to clip a song of a Black Throated Green Warbler from it.

Find a candidate song example

The R package monitoR has an easy tool for interacting with long (several minutes to several hour durations) audio files. To find one from your own recordings, load packages monitoR and tuneR from the package library and call the viewSpec function:

```
viewSpec('MABI02_A_052710.wav')
```

the R gui will display the available menu options. Options include moving page-by-page, saving the page as wav files, playing the survey, and zooming in/out.

Change recording sample rate of the template

For both sccCor and binaryPtMatch, the sampling rate of the template must match the survey. There are a number of ways to confirm that this is the case.
First, if you export a template from the survey the sampling rates will match by default. If you order one from the Macaulay library (or get it anywhere beside for your survey) you can read it into R using tuneR::readWave and adjust the sampling rate using monitoR::changeSampRate You will need to save the track again (tuneR::writeWave) for the changes to be saved. To check or change the sampling rate in R, load the tuneR package from your library, and assign your template to an object within R using the readWave command:

```
BTNW <- readWave('C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav')
```

Check the sample rate by viewing the details of your new object:

```
BTNW

Wave Object
      Number of Samples:      68212
      Duration (seconds):     2.84
      Samplingrate (Hertz):   24000
      Channels (Mono/Stereo): Mono
      Bit (8/16/24/32):       16
```

Change the sampling rate using the changeSampRate command, which spline-fits new sample values and can thus upsample:

```
BTNW<-changeSampRate(BTNW,sr.new=44100)
```

In tests conducted using synthesized and actual recordings, the changeSampRate function did not produce aliasing artifacts or other noticeable problems in spectrograms. However, these tests were limited, and spectrograms should be spot-checked after resampling to ensure that they closely match spectrograms from the original recording.

If your template is listed as Stereo you may opt to make it mono using tuneR's **channel** function. Choosing a single channel will save memory as it is loaded into R, plus it will reduce ambiguity if the signal in the two channels differs.

```
BTNW<-channel(BTNW,which=c('left'))
```

Substitute right for left if the signal is preferable in the right channel. It is not necessary to have a mono template, but the left channel is used by default.

Correlation Templates

There are two template matching algorithms in this package: correlation matching and binary point matching. The template building process is very similar for both of these algorithms, but the template structure is quite different.

When building a correlation template you will interactively define the boundary of the template in the spectrogram, effectively making a finer choice of time boundaries and applying a band-pass filter at the same time. The template defines not only where you want higher amplitudes in the spectrogram, but also where you want low amplitudes. Be sure to include both in your selection. Some of the methods below allow selection of multiple regions within the spectrogram, so the final selection need not be a rectangle. When choosing what low-amplitude regions to include in the template, a good place to begin is to consider what songs or noises might overlap the spectrogram you are working with and specifically include those regions as low-amplitude areas.

Create SCC Templates From Sound Clips: makeCorTemplate()

The arguments to makeCorTemplate can be viewed with the args command:

```
> args(makeCorTemplate)
function (clip, t.lim = NA, frq.lim=c(0,12), binary = FALSE, select =
      "click", dens = 1, buffer = 0, spec.cols = gray.2, col.sel =
      ifelse(dens == 1, "#99009975", "orange"), ...)
```

Where the "…" allows the user to add FFT parameter arguments. These arguments may include:

- wl to change window length (e.g. wl=1024; must be a power of 2. Common wls are 128, 256, 512, and 1024).
- ovlp to change window overlap: (e.g. ovlp=50; must be a percent between 0 and 99. Common ovlps are 0, 25, 50, and 75).
- wn to change window function: (e.g. wn='hamming'; others include the default 'hanning', 'blackman', 'rectangle', and 'triangle').

Detection of some calls may be improved by changing the FFT[2] window length, FFT overlap, or FFT window function. The default FFT parameters are typically suited for vocalizations that span a frequency band >= 1 kHz and have durations > 1 second. Vocalizations with durations < 1 second might benefit from increased time resolution, which is achieved with smaller window

[2] Fast Fourier Transformation

lengths (< 512). Vocalizations that span < 1kHz may benefit from more frequency resolution, which is achieved with longer window lengths (> 512). Increasing the overlap for longer window lengths allows some time resolution to be returned. Overlap is specified as a percentage ranging from 0 to 99; typical values are 0, 50, 75, and 95. Specifying new FFT parameters in the template will pass the parameters to the survey as well.

Begin by calling the function, adding values to arguments where no default is specified or where the default is not the desired value. At the minimum you must specify the wav clip to use, which can either be a quoted file path or an existing wav object read in using tuneR's readWave or readMP3 functions. Optionally you may identify the start and end of the clip (in seconds) if planning to use only a short segment of a longer file, change the frequency limits (in kHz), identify the selection method (choose either 'click', 'rect', 'auto', or 'line'—see descriptions and examples that follow), and identify how dense the points within the template will be (with the 'click' selection method use the default of dens=1; for other methods, if dens=1 all points within the selection area will be saved, and for dens less than 1 only the specified proportion of points will be chosen, e.g. dens=0.2 will save roughly every fifth point, dens=0.5 will save roughly every other point, etc).

A new window will open to display the spectrogram of the chosen clip. Time is labeled along the X axis, and frequency is labeled along the Y axis. The spectrogram is a matrix of time and frequency bins, and the corresponding bin numbers are labeled along the secondary X and Y axes.

If the selection method is set to 'click', you will be prompted to select individual points to include in the template. Do this by hovering your mouse over the points you intend to select and left-clicking each point. Right-click to end the selection process (choose "Stop" if prompted). Close the spectrogram window.

If the selection method is set to 'rect' or 'rectangle', you will be prompted to select the upper left corner of the rectangle. Do this by hovering your mouse over the spectrogram where you want the upper left corner to be and left-clicking (left-click and release). You will then be prompted to choose the lower right corner of the rectangle. Again, move your mouse and left-click to select the corner. A colored rectangle will fill the area between the two clicks; if the function call included the default dens=1, the rectangle will be a solid purple. If dens was set to less than 1, the rectangle will be dotted orange at roughly the density specified. You can select multiple rectangles per template to incorporate some areas while leaving out others. Right-click to end the selection process. Close the spectrogram window.

If the selection method is set to 'auto' the entire spectrogram within the specified t.lim values and frq.lim values will be selected at the specified dens proportion. The R gui will announce that automatic selection is done. Close the spectrogram window.

If the selection method is set to 'line' you will be prompted to choose either the upper or left start point of the line. Do this by hovering your mouse over the spectrogram and left-clicking at the desired location. Now you will be prompted to choose the lower or right point of the line. Again, move your mouse and left-click over the desired location. You may select multiple vertical and

or horizontal lines on the spectrogram. If the default dens=1 value is preserved the lines will appear as purple transects through the spectrogram; if dens is set to less than 1, the lines will appear as orange dotted lines at roughly the specified proportion. Right-click to end the selection process, and close the spectrogram window.

The four selection methods and the option to either accept the default dens=1 or choose a lower proportion means that there are at least eight different call combinations possible. The dens argument is continuous, so there are really far more than eight possible calls. Only a handful of possible calls are demonstrated below.

In the future you may save your templates and then call them back into R by name, so take a few minutes to develop a naming system that works for you. Names should be succinct, descriptive, and unique. The database will not allow duplicate names, and if you are not using the database duplicate names will create confusion in the future. The two parameters you will vary between templates are the FFT parameters and the density, so code them into the name if you are not accepting the default. If you are also building templates for binary point matching be sure to distinguish between those templates and correlation templates. You may use underscores and dashes in the names but do not use spaces, slashes, colons, semi-colons, periods, or commas as they may cause operating system or R errors when written to files.

Eleven non-exhaustive example calls to create templates are provided below, followed by a sequence of resulting spectrograms. Screen captures of some steps are omitted to save space. During these calls the R gui will offer prompts such as the one below, with the actions initiating the prompt change in italics:

```
Rectangular selection
Select upper left corner of rectangle with a left click. Right click to exit.
(first left click)
Select lower right corner of rectangle with a left click.
(second left click)
Select upper left corner of rectangle with a left click. Right click to exit.
(right click)
Done.
```

```
# Call 1: change only the selection type from the default point:
BTNW_rect_C<-makeCorTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
      select='rect')
# Call 2: use a descriptive name:
BTNW_rect_MandHnotes_C<-makeCorTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
      select='rect')
```

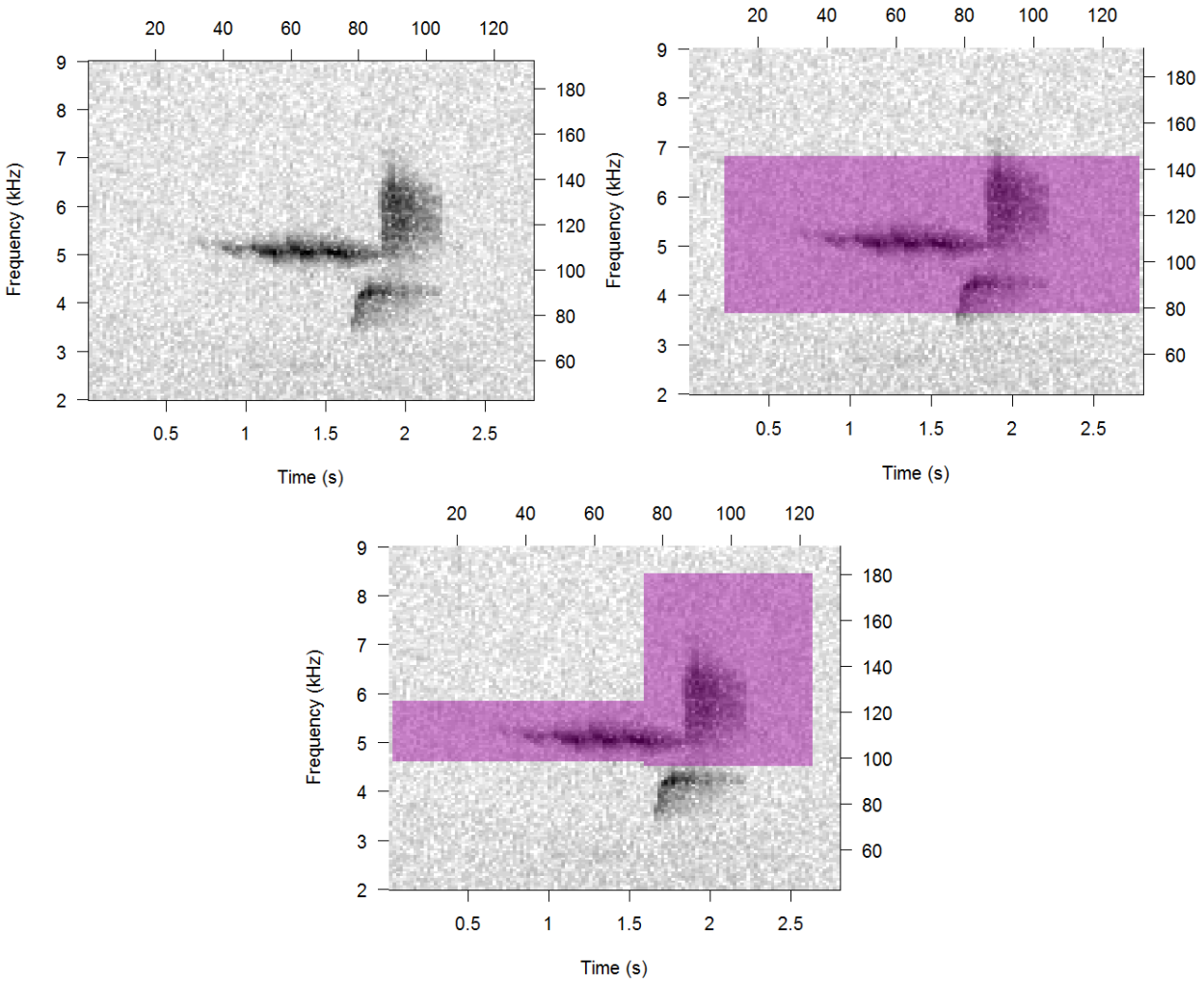


Figure S7.1. Top left: the initial spectrogram after calling makeCorTemplate(), before making any selections. Top right: call 1, after making a single rectangular selection. Bottom: call 2, after making two rectangular selections.

```
# Call 3: change the density to 0.8:
BTNW_rect_d80_C<-makeCorTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
      select='rect',
      dens=0.8)
# Call 4: change the density to 0.5:
BTNW_rect_d50_C<-makeCorTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
      select='rect',
      dens=0.5)
# Call 5: change the density to 0.2:
BTNW_rect_d20_C<-makeCorTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
      select='rect',
      dens=0.2)
```

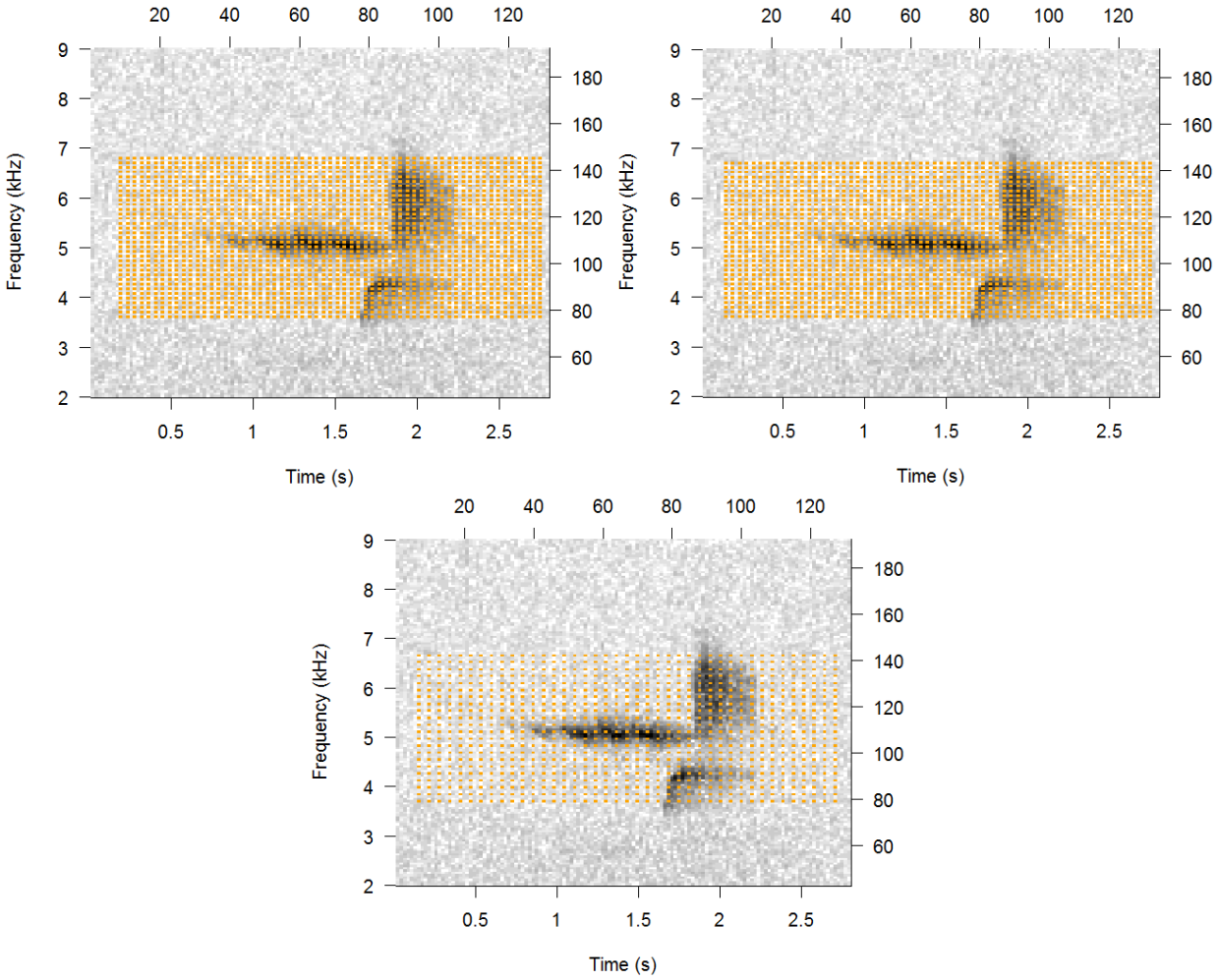


Figure S7.2. Top left: call 3, after making one selection at a density of 0.8. Top right: call 4, after making one selection at a density of 0.5. Bottom: call 5, after making one selection at a density of 0.2.

```
# Call 6: specify tighter time and frequency limits, use automatic selection:
BTNW_auto_d100_C<-makeCorTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
      t.lim=c(0.5,2.5),
      frq.lim=c(3.5,6.75),
```

```
      select='auto')
# Call 7: automatic selection at density 0.8:
BTNW_auto_d80_C<-makeCorTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
      t.lim=c(0.5,2.5),
      frq.lim=c(3.5,6.75),
      select='auto',
      dens=0.8)
# Call 8: automatic selection at density 0.2:
BTNW_auto_d20_C<-makeCorTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
      t.lim=c(0.5,2.5),
      frq.lim=c(3.5,6.75),
      select='auto',
      dens=0.2)
```

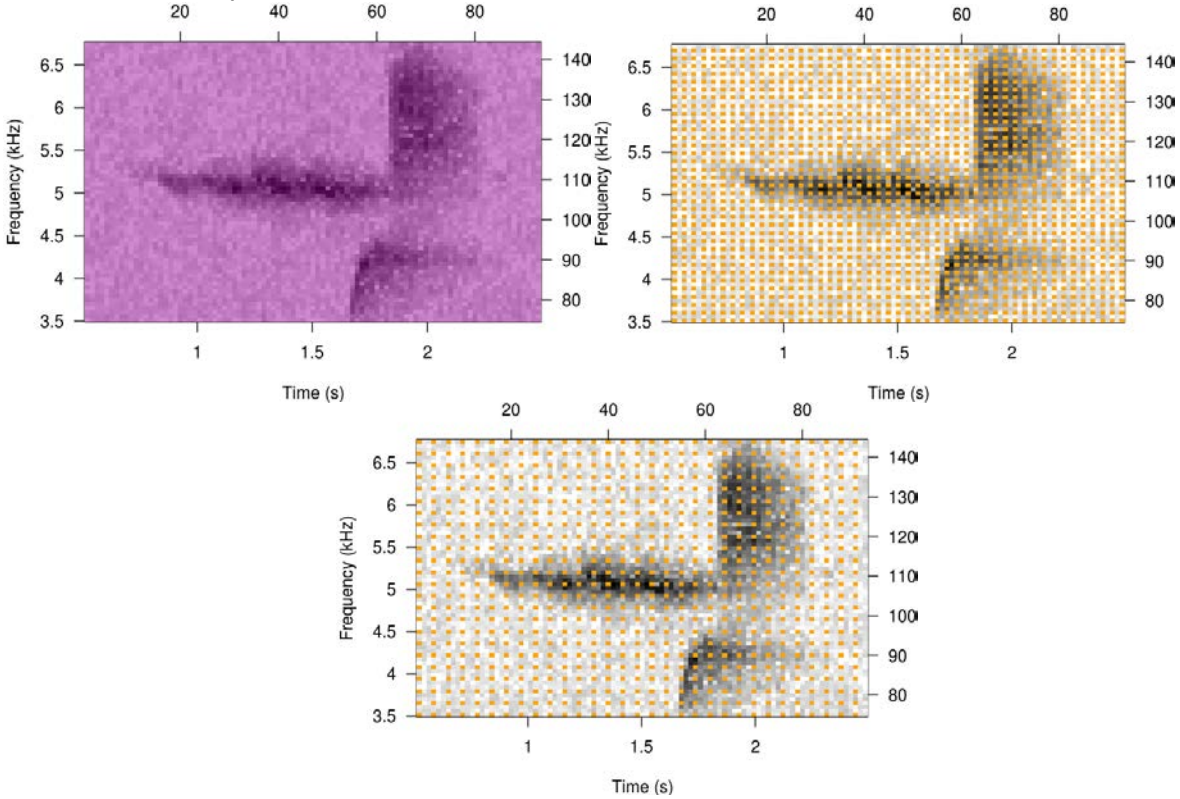


Figure S7.3. Automatic selection at different densities. Top left: call 6, at density of 1.0. Top left: call 7, at a density of 0.8. Bottom: call 8, at density of 0.2.

```
# Call 9: line selection:
BTNW_line_d100_C<-makeCorTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
      select='line')
# Call 10: line selection at density 0.5:
BTNWline0.5_C<-makeCorTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
      select='line',
      dens=0.5)
# Call 11: point selection:
BTNW_click_allNotes_C<-makeCorTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
```

```
select='click')
```

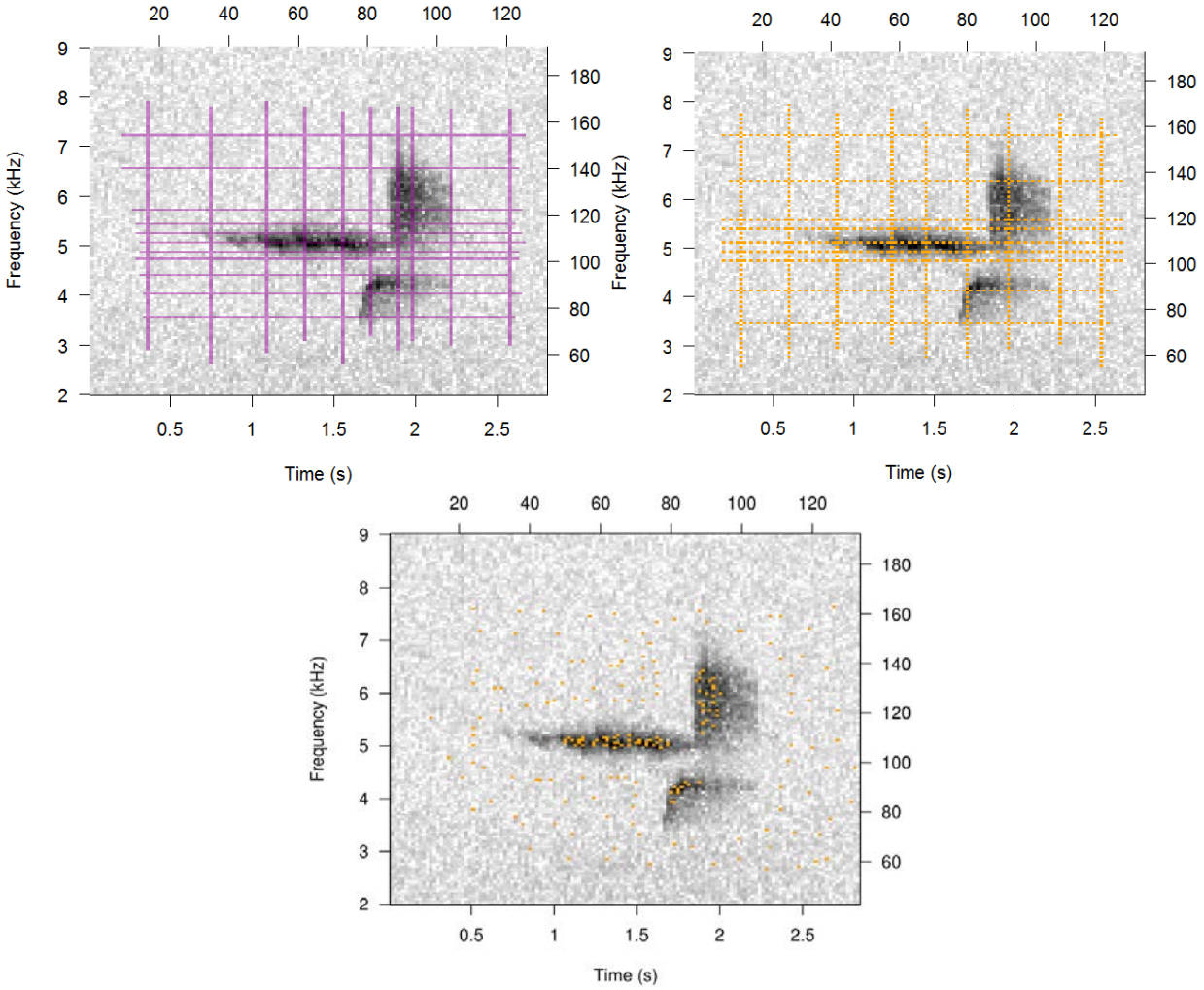


Figure S7.4. Top left: call 9, line selection at density 1.0. Top right: line selection, call 10, at density 0.5. Bottom: point (click) selection.

Combine templates for uninterrupted analysis, adjust score.cutoff, rename them

Templates can be used for spectrogram cross correlation as soon as they are made, but to scan a survey with multiple templates you must combine them into a list. It is possible to combine templates with multiple FFT parameters into a list, but the FFT will need to be recomputed for each template, which will add several seconds to each pass. Combining the templates will also expedite saving them for future use, either locally or in a database. The combineCorTemplates function is demonstrated below.

```
# This call assigns a default score.cutoff for all templates
CORtemplates<-combineCorTemplates(
      BTNW_rect_C,
      BTNW_rect_MandHnotes_C,
      BTNW_rect_d80_C,
      BTNW_rect_d50_C,
      BTNW_rect_d20_C,
      BTNW_auto_d100_C,
```

```
      BTNW_auto_d80_C,
      BTNW_auto_d20_C,
      BTNW_line_d100_C,
      BTNWline0.5_C)

# Miss one? Add templates to that list as well:
CORtemplates<-combineCorTemplates(CORtemplates,BTNW_click_allNotes_C)
# This call revises the default score.cutoff of 0.1 with a unique value for
each template
CORtemplates<-templateCutoff(
      CORtemplates,
      score.cutoff=c(
            BTNW_rect_C=0.4,
            BTNW_rect_MandHnotes_C=0.45,
            BTNW_rect_d80_C=0.41,
            BTNW_rect_d50_C=0.38,
            BTNW_rect_d20_C=0.42,
            BTNW_auto_d100_C=0.41,
            BTNW_auto_d80_C=0.4,
            BTNW_auto_d20_C=0.35,
            BTNW_line_d100_C=0.29,
            BTNWline0.5_C=0.42,
            BTNW_click_allNotes_C=0.41))
# This call assigns a new default value for all templates
CORtemplates<-templateCutoff(
      CORtemplates,
      score.cutoff=c(default=0.40))
# Rename templates too:
CORtemplates<-templateNames(CORtemplates,c(…vector of new names…))
```

The print method for this class returns a summary of all templates in the list when called:

```
> CORtemplates
Object of class "corTemplateList"
      containing 11 templates
                                        original.recording sample.rate
BTNW_auto_d100_C       ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
BTNW_auto_d20_C        ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
BTNW_auto_d80_C        ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
BTNW_click_allNotes_C  ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
BTNWline0              ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
BTNW_line_d100_C       ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
BTNW_rect_C            ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
BTNW_rect_d20_C        ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
BTNW_rect_d50_C        ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
BTNW_rect_d80_C        ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
BTNW_rect_MandHnotes_C ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
                       lower.frequency upper.frequency lower.amp upper.amp
BTNW_auto_d100_C                 3.516           6.750   -94.710     0.000
BTNW_auto_d20_C                  3.516           6.750   -81.874    -1.993
BTNW_auto_d80_C                  3.516           6.703   -81.843    -3.428
BTNW_click_allNotes_C            1.359           9.562   -76.263    -3.203
BTNWline0                        1.359           9.797   -78.076    -4.641
BTNW_line_d100_C                 1.641          10.078   -86.965    -2.814
BTNW_rect_C                      3.141           7.453   -86.965     0.000
BTNW_rect_d20_C                  2.578           7.219   -83.995    -5.877
```

```
BTNW_rect_d50_C                 2.953           7.547   -82.282    -2.098
BTNW_rect_d80_C                 3.234           7.078   -82.282    -2.098
BTNW_rect_MandHnotes_C          2.250           8.719   -89.012     0.000
                        duration n.points score.cutoff
BTNW_auto_d100_C           1.963     6510         0.41
BTNW_auto_d20_C            1.920      744         0.35
BTNW_auto_d80_C            1.963     1645         0.40
BTNW_click_allNotes_C      2.347      197         0.41
BTNWline0                  2.091      967         0.42
BTNW_line_d100_C           2.112     2209         0.29
BTNW_rect_C                2.155     9486         0.40
BTNW_rect_d20_C            1.984     1088         0.42
BTNW_rect_d50_C            1.963     2350         0.38
BTNW_rect_d80_C            2.048     2058         0.41
BTNW_rect_MandHnotes_C     2.347     7629         0.45
```

Binary Point Templates From a Single Song

The second type of template is a binary point template. The building process is similar to that for correlation templates, but the template structure is different: binary point templates do not contain amplitude information from the song clip used to build them. Instead, the template provides coordinates of where to make amplitude comparisons for each potential detection; these coordinates combine into something like a map.

The features of interest in the map are locations with signal and locations with noise. These are saved as either ‘on’ or ‘off’ points, where ‘on’ points correspond to signal and ‘off’ points to noise. Constructing a binary template is a means of choosing the on and off points while looking at an example song clip for guidance.

Click, Rectangle, Automatic, and Line Selections

Use the args call to view the arguments for the makeBinTemplate function:

```
> args(makeBinTemplate)
function (clip, t.lim = c(0, Inf), frq.lim, binary = FALSE, select = "click",
      dens = 1, buffer = 0, spec.cols = spec.palette, amp.cutoff = "i", ...)
```

Where the “…” allows the user to add FFT parameter arguments. These arguments may include:

- wl to change window length (e.g. wl=1024; must be a power of 2. Common wls are 128, 256, 512, and 1024).
- ovlp to change window overlap: (e.g. ovlp=50; must be a percent between 0 and 99. Common ovlps are 0, 25, 50, and 75).
- wn to change window function: (e.g. wn='hamming'; others include the default 'hanning', 'blackman', 'rectangle', and 'triangle').

Detection of some calls may be improved by changing the FFT[3] window length, FFT overlap, or FFT window function. The default FFT parameters are typically suited for vocalizations that span a frequency band >= 1 kHz and have durations > 1 second. Vocalizations with durations < 1 second might benefit from increased time resolution, which is achieved with smaller window lengths (< 512). Vocalizations that span < 1kHz may benefit from more frequency resolution, which is achieved with longer window lengths (> 512). Increasing the overlap for longer window lengths allows some time resolution to be returned. Overlap is specified as percents ranging from 0 to 99; typical values are 0, 50, 75, and 95. Specifying new FFT parameters in the template will pass the parameters to the survey as well.

The process of making a binary point template will follow these general steps:
Call the function: specify the wav clip to use, identify the start and end of it (in seconds) and the frequency limits (in kHz), identify the selection method (choose either 'click', 'rect', or 'auto'), and identify how dense the points within the template will be (with the 'click' selection method use the default of dens=1 and the default of binary=FALSE; for other methods choose binary=TRUE, and if dens=1 all points within the selection area will be saved, and for dens less than 1 only the specified proportion of points will be chosen. Dens=0.2 will save roughly every fifth point, dens=0.5 will save roughly every other point, etc). The binary template has the option to include a buffer around signal points; if the buffer=0, off points will be selected adjacent to on points. If the buffer is greater than 0, off points can only approach on points to the edge of the buffer. The binary aspect of the template building process allows you to view the song clip as either signal or noise, and the user can specify the threshold that separates the two. If you already know what amplitude threshold to use for the binary spectrogram you can set that in the call, or leave it out to adjust it in the next step.

A new window will open to display the spectrogram of the chosen clip. Time is labeled along the X axis, and frequency is labeled along the Y axis. The spectrogram is a matrix of time and frequency bins, and the corresponding bin numbers are labeled along the secondary X and Y axes.

If binary=FALSE the spectrogram will be displayed in the assigned color palette. If binary=TRUE the spectrogram will be black and white. If the amplitude cutoff was not set in the function call, you will be prompted to raise or lower the threshold by typing 'h' or 'l' (higher or lower) and pressing Enter. You can adjust it in broader steps by typing in more than one character: 'hhh' raises the threshold more than 'h'-Enter-'h'-Enter-'h'-Enter, and you can enter as many as five characters at once. When only the signal remains black and the noise is white press Enter once more to begin point selection.

If the selection method is set to 'click', you will be prompted to select individual points to include as on and off points in the template. Do this by hovering your mouse over the points you

[3] Fast Fourier Transformation

intend to select and left-clicking each point. Right-click to end the on point selection process, and the R gui will prompt you to choose off points. Do this by hovering your mouse over the points you intend to select and left-clicking each point. Right-click to end the off point selection process. Close the spectrogram window.

If the selection method is set to ‘rect’ or ‘rectangle’, you will be prompted to select the upper left corner of a rectangle in which all signal points will be selected as on points. Do this by hovering your mouse over the spectrogram where you want the upper left corner to be and left-clicking (left-click and release). You will then be prompted to choose the lower right corner of the rectangle. Again, move your mouse and left-click to select the corner. All on points within the rectangle will fill with a transparent color; if the function call included the default dens=1, the on points will be a solid orange. If dens was set to less than 1, the on points will be dotted orange at roughly the density specified. You can select multiple rectangles per template to incorporate some areas while leaving out others. Right-click to end the on point selection process. You will now be prompted to select the upper left corner of a rectangle in which all noise points will be selected as off points. Do this by hovering your mouse over the spectrogram where you want the upper left corner to be and left-clicking. You will then be prompted to choose the lower right corner of the rectangle. Again, move your mouse and left-click to select the corner. All of points within the rectangle will fill with a transparent color; if the function call included the default dens=1, the on points will be a solid blue. If dens was set to less than 1, the on points will be dotted blue at roughly the density specified. You can select multiple rectangles per template to incorporate some areas while leaving out others. Right-click to end the off point selection process. Close the spectrogram window.

If the selection method is set to ‘auto’ and no amplitude cutoff value is supplied you will be asked to select a threshold using the ‘h’ and ‘l’ raising/lowering process. When you have pressed Enter twice, the entire spectrogram within the specified t.lim values and frq.lim values will be selected as on and off points at the specified dens proportion. The R gui will announce that automatic selection is done. Close the spectrogram window.

The three selection methods, the option to either accept the default dens=1 or choose a lower proportion, and the option to use a buffer or not means that there are at least 12 different call combinations possible. The dens and buffer arguments are continuous, so there are really far more than 12 possible calls. Only a handful of possible calls are demonstrated below.

In the future you may save your templates and then call them back into R by name, so take a few minutes to develop a naming system that works for you. Names should be succinct, descriptive, and unique. The database will not allow duplicate names, and if you are not using the database duplicate names will create confusion in the future. The three parameters you will vary between templates are the FFT parameters, the density, and the buffer size, so code them into the name if you are not accepting the default. If you are also building templates for correlation analysis be sure to distinguish between those templates and binary point templates. You may use underscores and dashes in the names but do not use spaces, slashes, colons, semi-colons, periods, or commas as they may cause operating system or R errors when written to files.

Five non-exhaustive example calls to create templates are provided below, followed by a sequence of resulting spectrograms. Screen captures of some steps are omitted to save space. During these calls the R gui will offer prompts such as the ones below for “click” point selection, with the actions initiating the prompt change in italics:

```
Interactive amplitude cutoff selection.
Enter l, ll, ll, etc. for lower cutoff, h, hh, hhh, etc. for higher cutoff,
or hit Enter to continue
Current cutoff: -51.
1: hhhhh
Current cutoff: -31.
1:
(Enter)
Select "on" points with left mouse click. To continue, right click.
(25 left clicks)
(right click)
25 selected
Select "off" points with left mouse click. When done, right click.
(73 left clicks)
(right click)
73 selected
Done.
```

```
# Call 1, using “rect” selection and the default density and buffer values:
BTNW_rect_d100_B<-makeBinTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
      t.lim=c(0,2.8),
      frq.lim=c(2,9),
      select='rect',
      binary=TRUE)
```

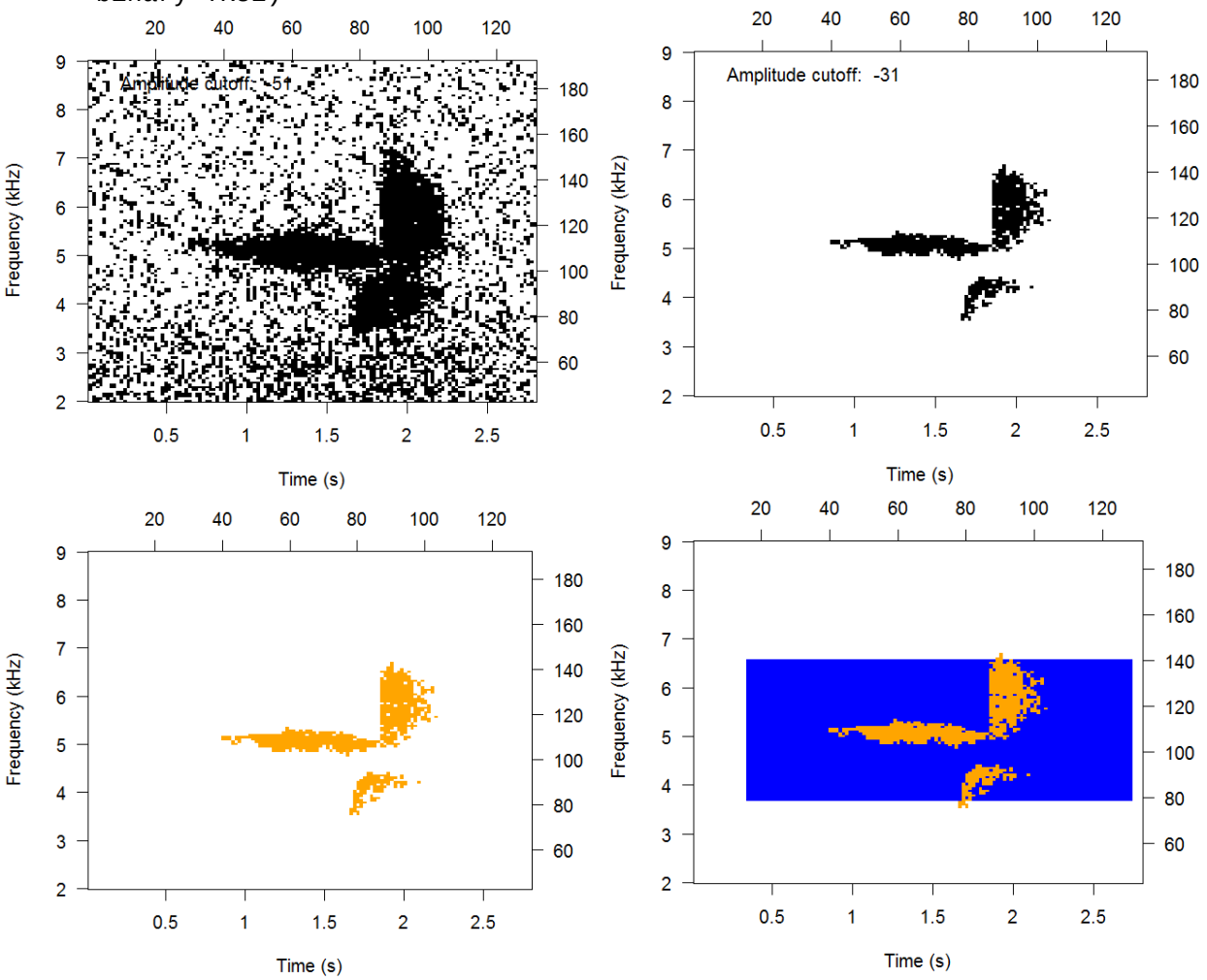
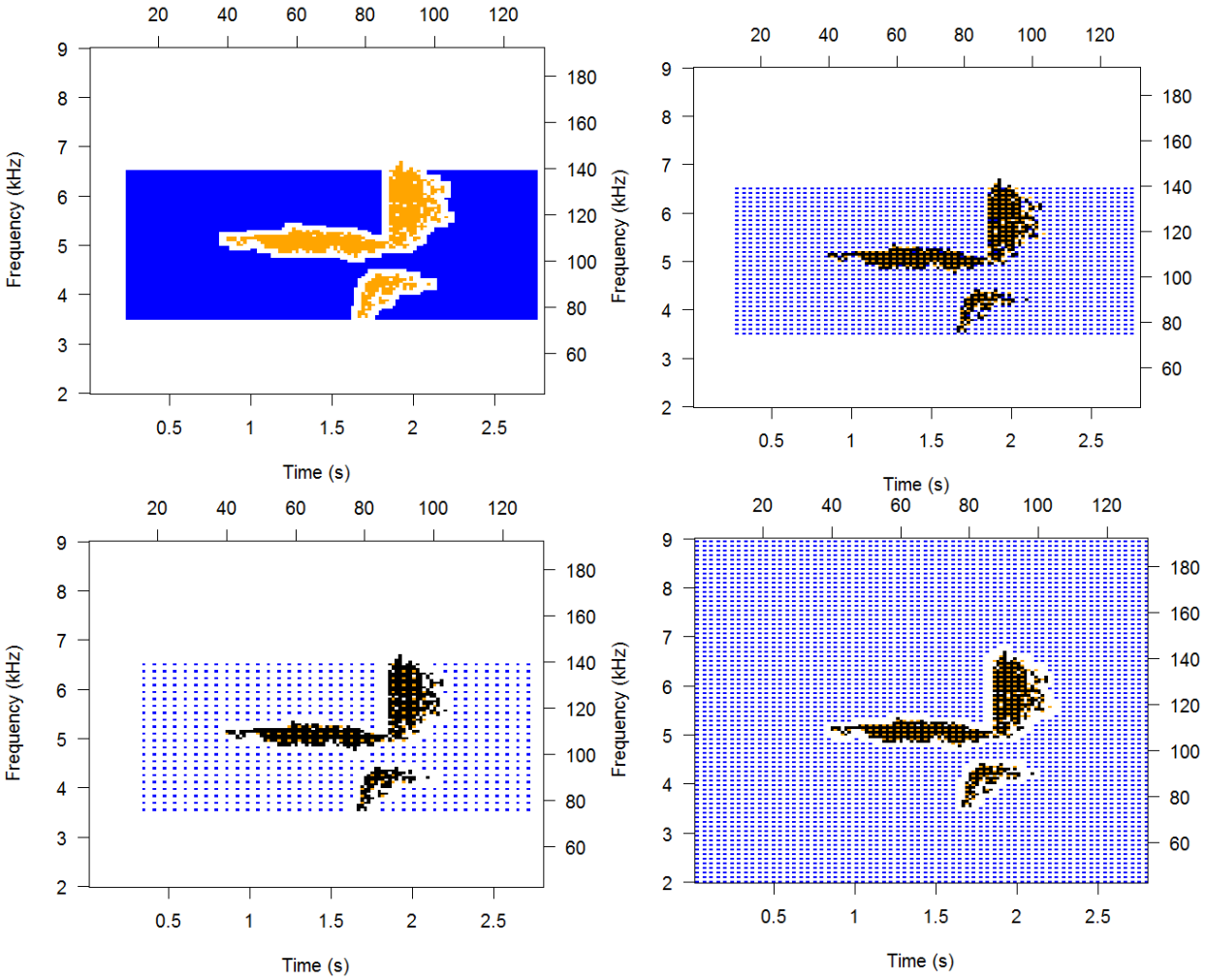


Figure S7.5. Top left: with binary=TRUE, the template opens with a default amplitude cutoff of -51dB; plenty of noise is visible over the cutoff. Top right: after raising the cutoff to -31dB only signal remains visible. Bottom left: call 1 (dens=1 and buffer=0) after ‘on’ point selection; the on points are colored orange. Bottom right: call 1 after ‘off’ point selection; the on points remain orange and the off points are colored blue.

```
# Call 2, specifying a buffer:
BTNW_rect_d100_b2_B<-makeBinTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
      t.lim=c(0,2.8),frq.lim=c(2,9),select='rect',buffer=2,binary=TRUE)
# Call 3, using density and buffer arguments:
BTNW_rect_d20_b2_B<-makeBinTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
      t.lim=c(0,2.8),frq.lim=c(2,9),select='rect',binary=TRUE,
      buffer=2,dens=0.2)
# Call 4, using the “auto” selection method:
BTNW_auto_d80_b2_B<-makeBinTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
      t.lim=c(0,2.8),frq.lim=c(2,9),select='auto',dens=0.8,
      buffer=2,binary=TRUE)
```



FigureS7.62. Top left: call 2 (after raising amp.cutoff to -31dB, dens=1, and buffer=2). The off points are all at least two time and/or frequency bins away from the on points. Top right: call 3 (after raising amp.cutoff to -31dB, dens=0.8, buffer=0) after on and off point selection. Bottom left: call 3 (after raising amp.cutoff to -31dB, dens=0.2, buffer=2). Bottom right: call 4 (after raising amp.cutoff to -31dB, dens=0.8, buffer=2, select='auto').

```
# Call 5 demonstrating the “click” selection system
      BTNW_click_d100_B<-makeBinTemplate(
      clip='C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav',
      t.lim=c(0,2.8),
      frq.lim=c(2,9),
      select='click')
```

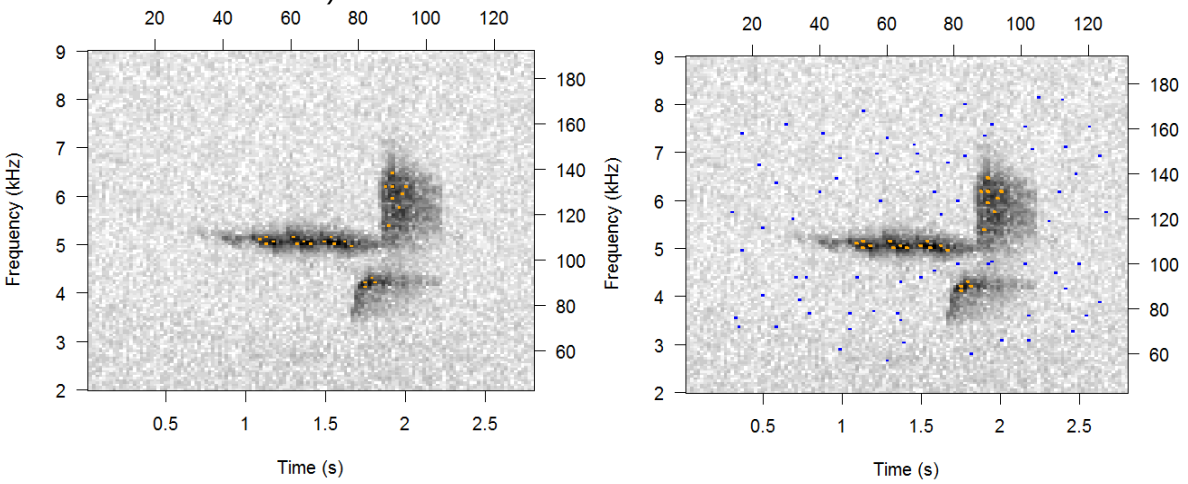


Figure S7.7. Left: call 5; with binary=FALSE and select='click' on point selection is done by choosing individual points, one at a time. Right: call 5; after right-clicking to stop on point selection off point selection is done one point at a time as well.

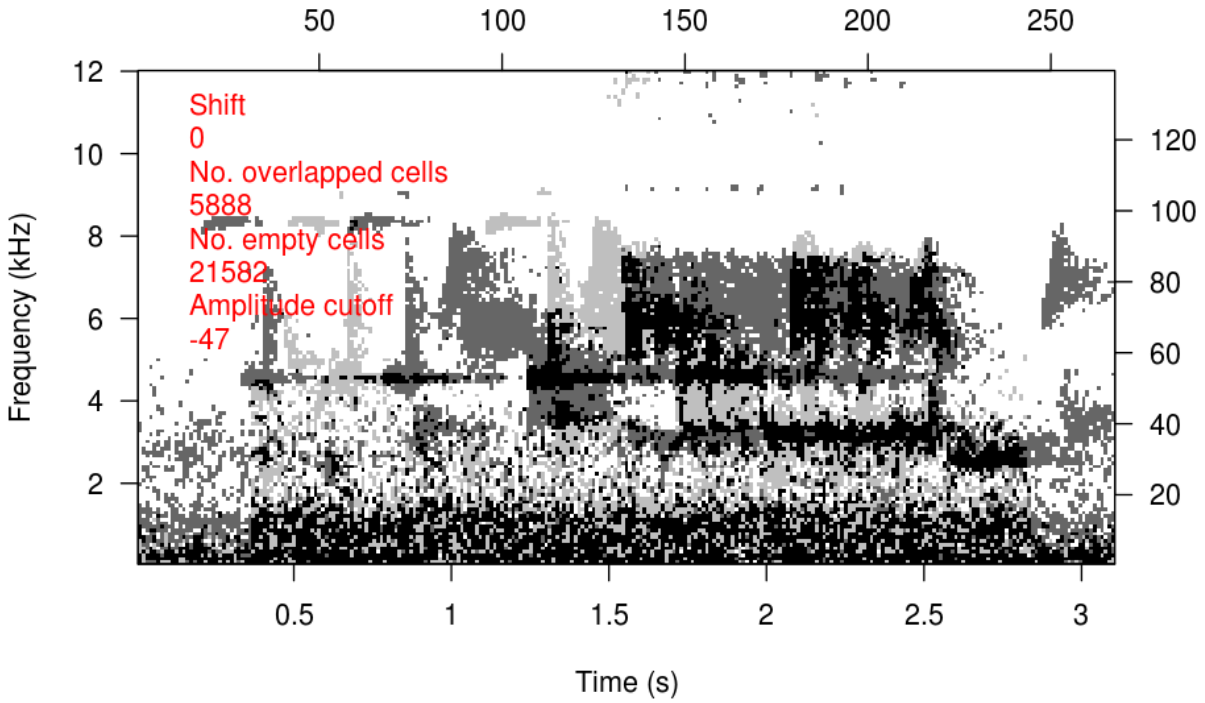
Binary Point Templates From Multiple Songs

It is possible to create a template from two example songs to better select notes or syllables that are common to each. In this process two example clips are visually overlaid upon one another to identify regions of overlap. This process works most effectively when the two song examples have reasonably high - or at least very similar - signal:noise ratios. As with binary point template construction from a single clip the amplitude threshold is selected first, then the user slides the first clip over the second until they are aligned as desired, and finally on and off point identification proceeds with either click, rectangle, or automatic selection. The template will store only the path to the second clip for future plotting.

Single point selection

Manually selecting a handful of on and off points will offer the greatest speed advantage and a lot of flexibility to include or ignore acoustic features, but to achieve the increased speed some template selectivity will be traded. To begin this process, assign the output of the makeBinTemplate2 function to an object. This function requires two clip paths to songs with identical sampling rates that are joined in a list, and the time limits (a list of vectors with the min and max time for each clip) set for each clip must be of equal duration. Frequency limits are a single vector for the spectrogram, and set select= 'point':

```
# Call 1, two Song Sparrow clips using click selection
SOSP_click_midphrase_B<-makeBinTemplate2(
      clip.L=list(
      s6='/home/jkatz3/Dropbox/UVMacoustic/Analysis/bird/Recordings/s6.wav',
      s7='/home/jkatz3/Dropbox/UVMacoustic/Analysis/bird/Recordings/s7.wav'),
      t.lim.L=list(c(1.4,4.5),c(1,4.1)),
      select='click',
      name='SOSP_click_midphrase_B')
```



FigureS7.8. Call 1; the first clip is displayed as dark gray, the second as light gray, and regions of overlap above the designated amplitude threshold are black. These two Song Sparrow songs share an introductory phrase but not an ending phrase.

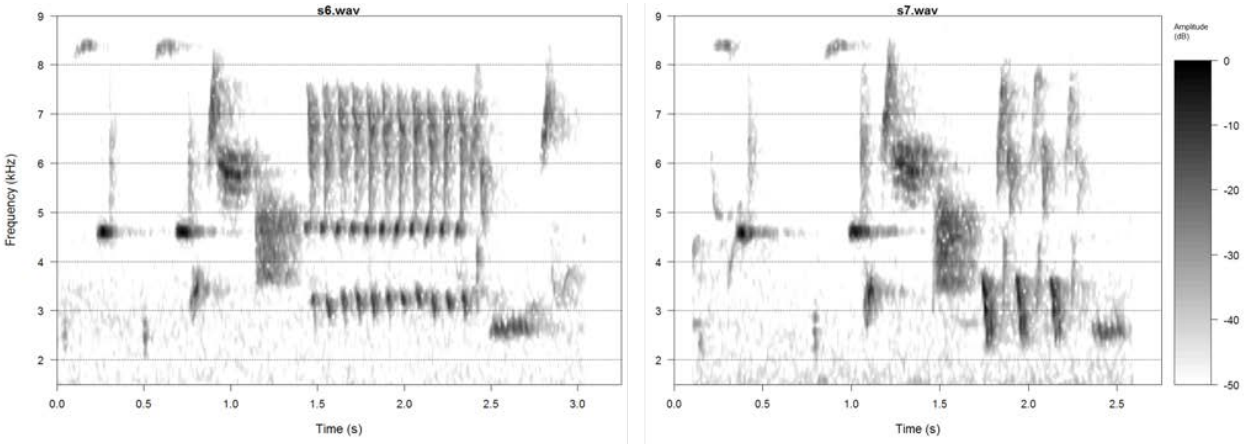


Figure S7.9. The two Song Sparrow spectrograms in call 1 viewed individually. Without overlaying them it is not obvious that the pair of introductory notes are not a perfect match.

The first task is to adjust the amplitude cutoff to include only the amplitudes that correspond to the syllables of the two songs. In this example the amplitude cutoff is too low - a lot of background noise is displayed, and our goal is to only display the syllables of the song - so the first adjustment is to raise the cutoff. The R gui displays instructions on how to do this:

```
Amplitude cutoff selection. Enter l, ll, ll, etc. for lower cutoff, h, hh,
      hhh, etc. for higher cutoff
1: hhhhh
1: ll
1: ll
```

```
1: ll
1:
```

This is a trial and error approach, and a final value will be subjective. When satisfied with the final appearance press Enter.

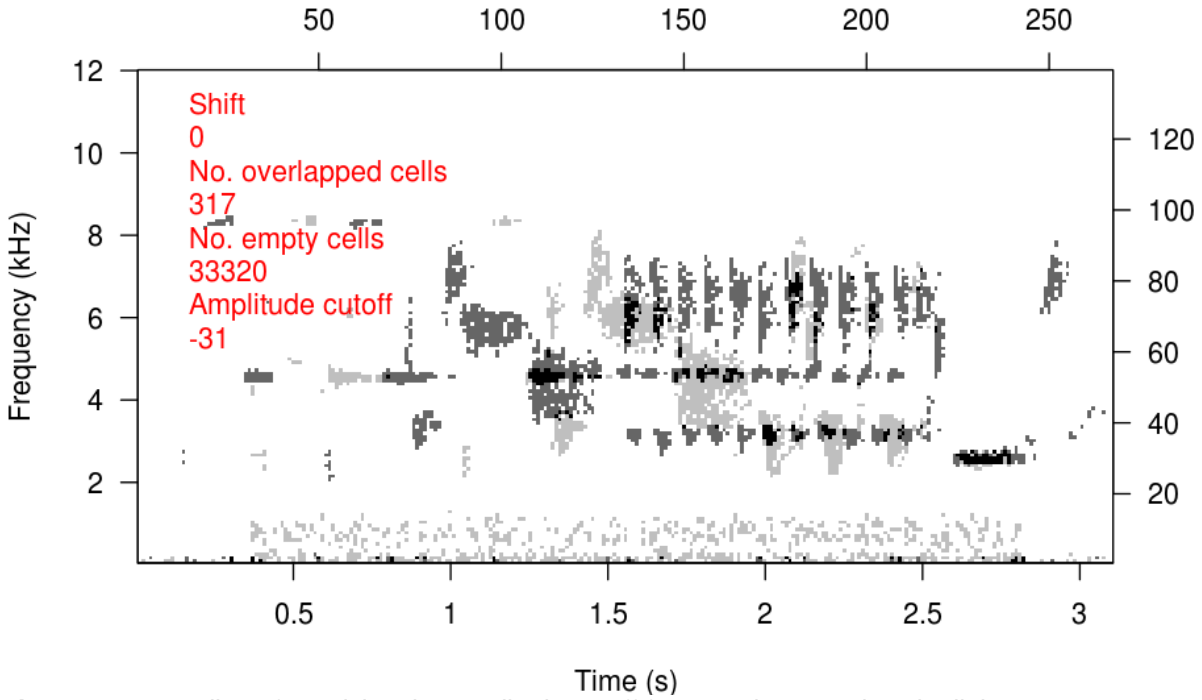


Figure S7.10. Call 1, after raising the amplitude cutoff from -47dB to -31dB. The light gray spectrogram is several time bins to the right of the dark gray spectrogram.

The next step is to time-align the two sound clips. Again, the R gui prints instructions on how to do this:

```
Time shift selection. Enter l, ll, ll, etc. for left shift, r, rr, rrr, etc.
      for right shift
1: lllll
1: lllll
1: r
1:
```

Enter the commands into the R gui, and press Enter.

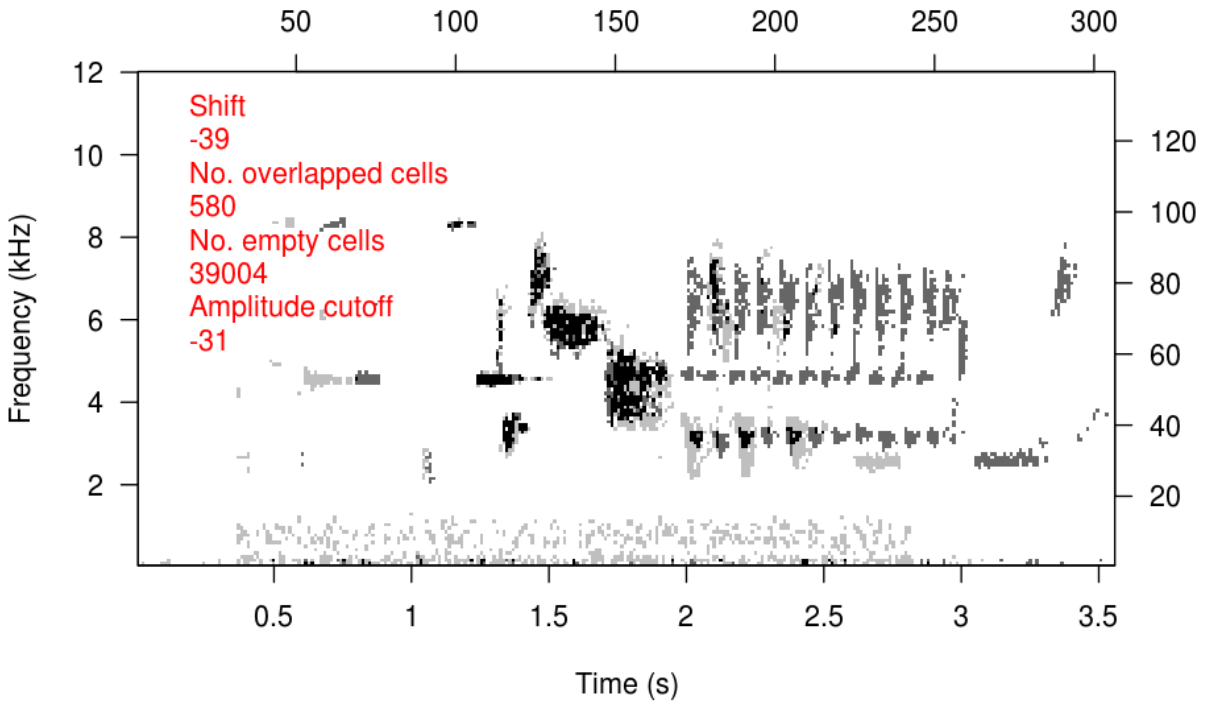


Figure S7.11. Call1; After shifting the light gray spectrogram to the left the number of overlapping cells has increased from 317 to 580.

The next step is on point selection. The R gui again provides instructions on how to do this:

```
Point-by-point point selection. Select "on" points with left mouse click.
      When done, right click.
```

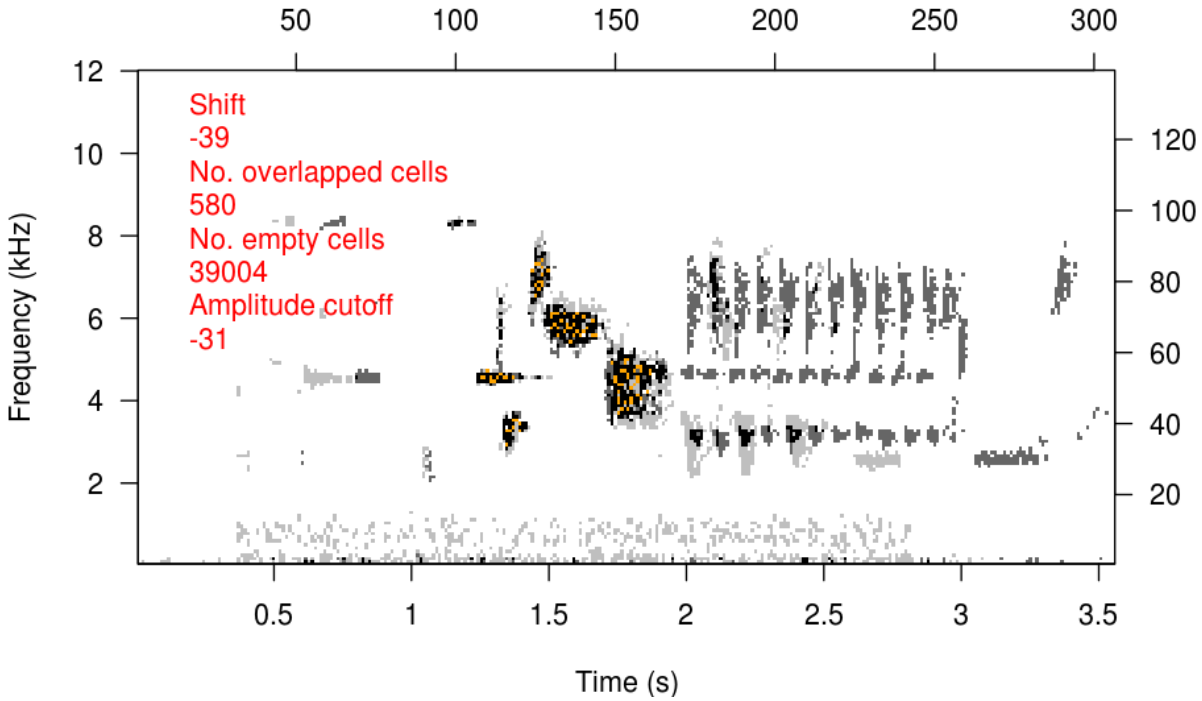


Figure S7.12. Call 1, after on point selection. The on points should fall within the black spectrogram which is composed of syllables common to both sound examples, but it is not necessary to select all black cells—nor is it necessary to select black cells from all syllables.

Next is off point selection. The R gui has instructions for this as well.

```
Select "off" points with left mouse click. When done, right click.
```

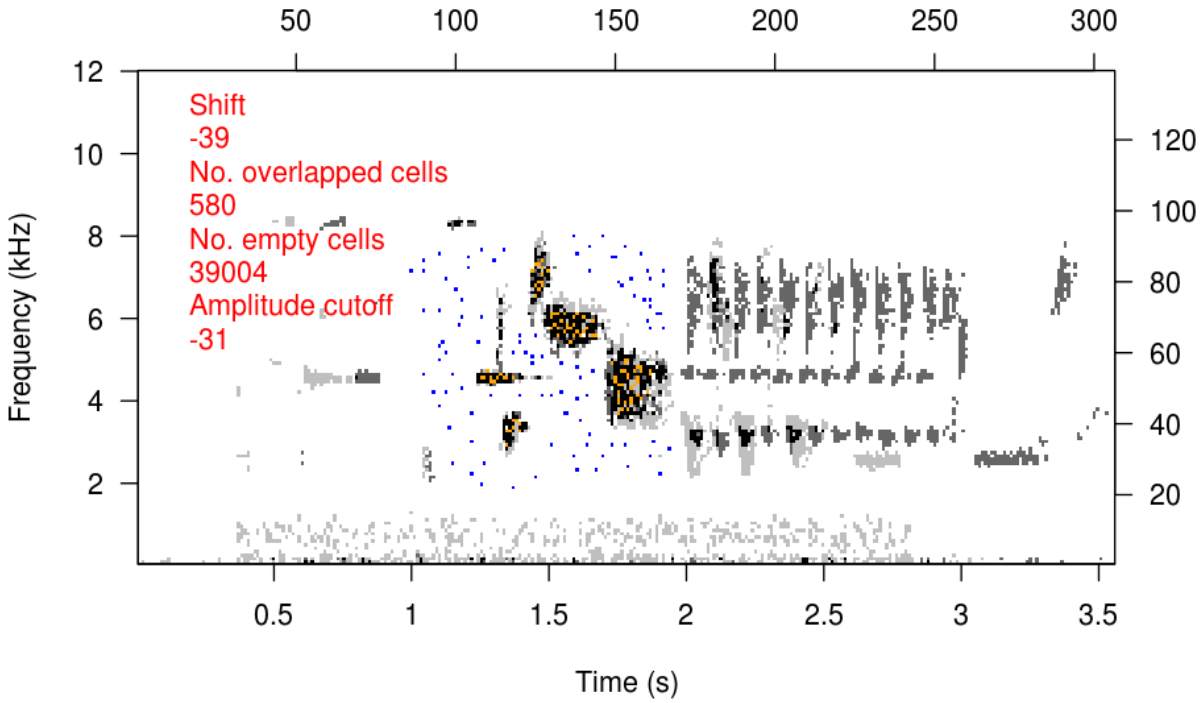


Figure S7.13. Call 1, after off point selection.

Rectangular point selection

An alternative to choosing just a handful of on or off points is to block out regions of points to be on points and make other blocks of regions to be off points. This approach will select all points above the amplitude threshold and within the initial blocks to be on points, and all points below the threshold and within the appropriate blocks to be off points.

```
# Call 2, two Song Sparrow clips using click selection
SOSP_rect_d80_b3_midphrase_B<-makeBinTemplate2(
      clip.L=list(
      s6='/home/jkatz3/Dropbox/UVMacoustic/Analysis/bird/Recordings/s6.wav',
      s7='/home/jkatz3/Dropbox/UVMacoustic/Analysis/bird/Recordings/s7.wav'),
      t.lim.L=list(c(1.4,4.5),c(1,4.1)),
      select='rect',
      buffer=3,
      dens=0.8,
      amp.cutoff=-31,
      name='SOSP_rect_d80_b3_midphrase_B')
```

To enable rectangular point selection we use the same command as above, but change the argument for select to ‘rect’:

In this call the amplitude cutoff is explicitly defined to save time, but the time shift procedure must be repeated as above. Specifying a buffer of 3 prevents any off point from being within 3 time or frequency bins proximity to a signal point, regardless of whether the signal exist in both clips. Setting dens=0.5 reduces the number of points selected in the matrix, and roughly half of the available points will be saved. When it is time to select on cells you should see this prompt in the R gui:

```
Rectangular selection. Select upper left corner of 'on' rectangle with a left
click. Right click to exit.
```

After left clicking once, the prompt in the gui changes:

```
Select lower right corner of 'on' rectangle with a left click.
```

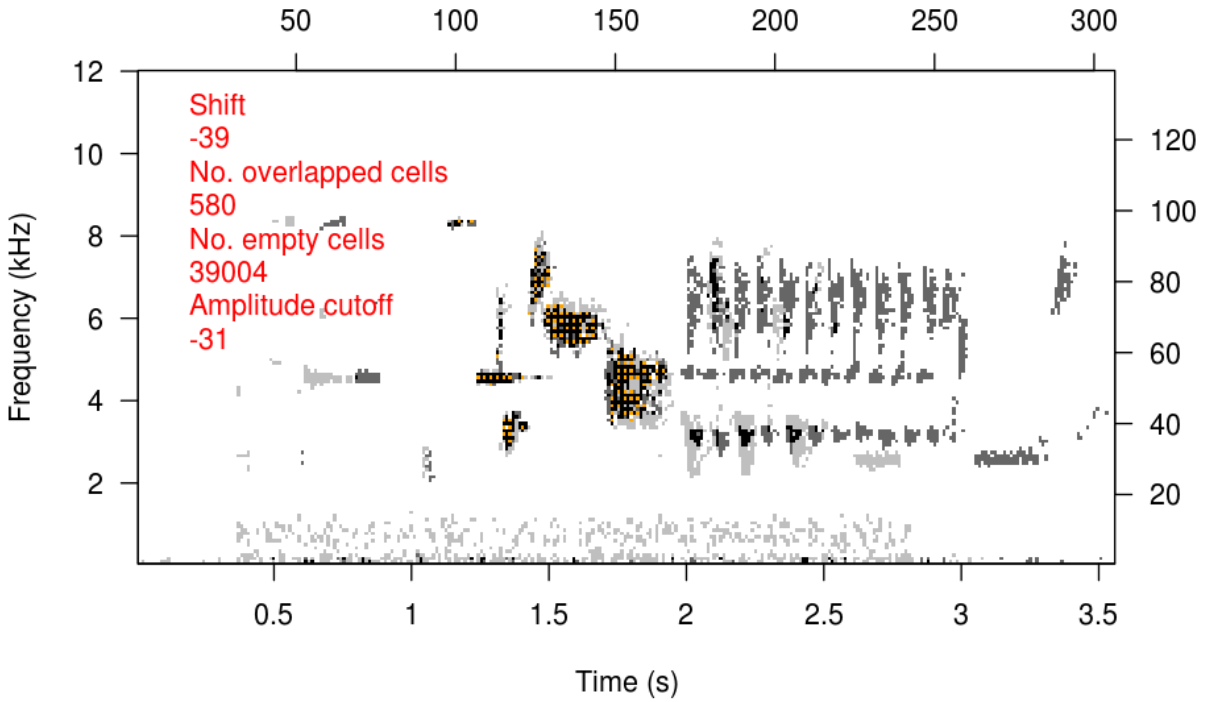


Figure S7.14. Call 2; Rectangular area selection. The reduced density appears as a dotted matrix of on points.

Right click to end on point selection, or left-click on the spectrogram to add additional on point rectangles.

After right-clicking the prompt in the gui changes again:

```
Select upper left corner of 'off' rectangle with a left click. Right click to exit.
```

After the first left click a new prompt appears:

```
Select lower right corner of 'off' rectangle with a left click.
```

All points in the matrix between the two selected corner points are designated as off points.

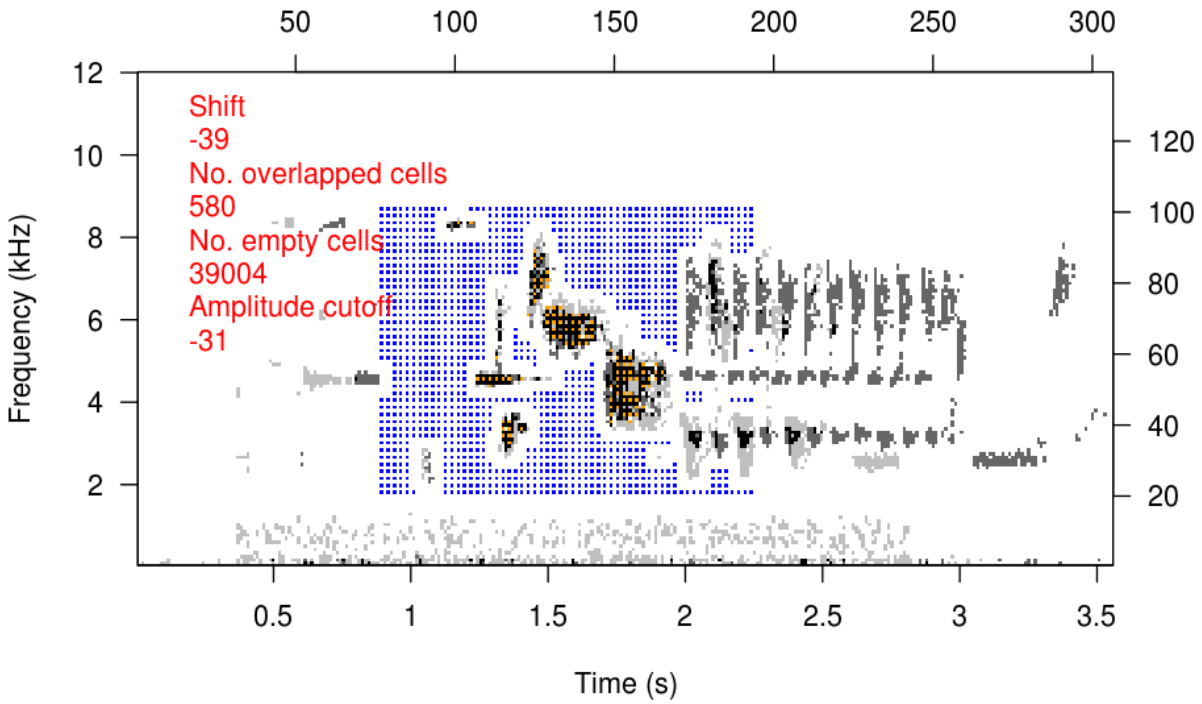


Figure S7.15. Call 2, after off point selection with a 3-point buffer.

Right-click to end point selection, or additional off points can be selected by selecting additional rectangles.

Automatic point selection

This third option will automatically cast all overlapped cells above the specified threshold as on points and all those below the threshold as off points. This option is enabled by changing the select argument to 'auto', as in the following command:

```
# Call 3, two Song Sparrow clips using click selection
SOSP_auto_d50_b4_midphrase_B<-makeBinTemplate2(
      clip.L=list(
      s6='/home/jkatz3/Dropbox/UVMacoustic/Analysis/bird/Recordings/s6.wav',
      s7='/home/jkatz3/Dropbox/UVMacoustic/Analysis/bird/Recordings/s7.wav'),
      t.lim.L=list(c(1.4,4.5),c(1,4.1)),
      frq.lim=c(2,8),
      select='auto',
      amp.cutoff=-31,
      dens=0.5,
      buffer=4,
      name='SOSP_auto_d50_b4_midphrase_B')
```

After setting the amplitude cutoff and time shift the automatic point selection takes place:

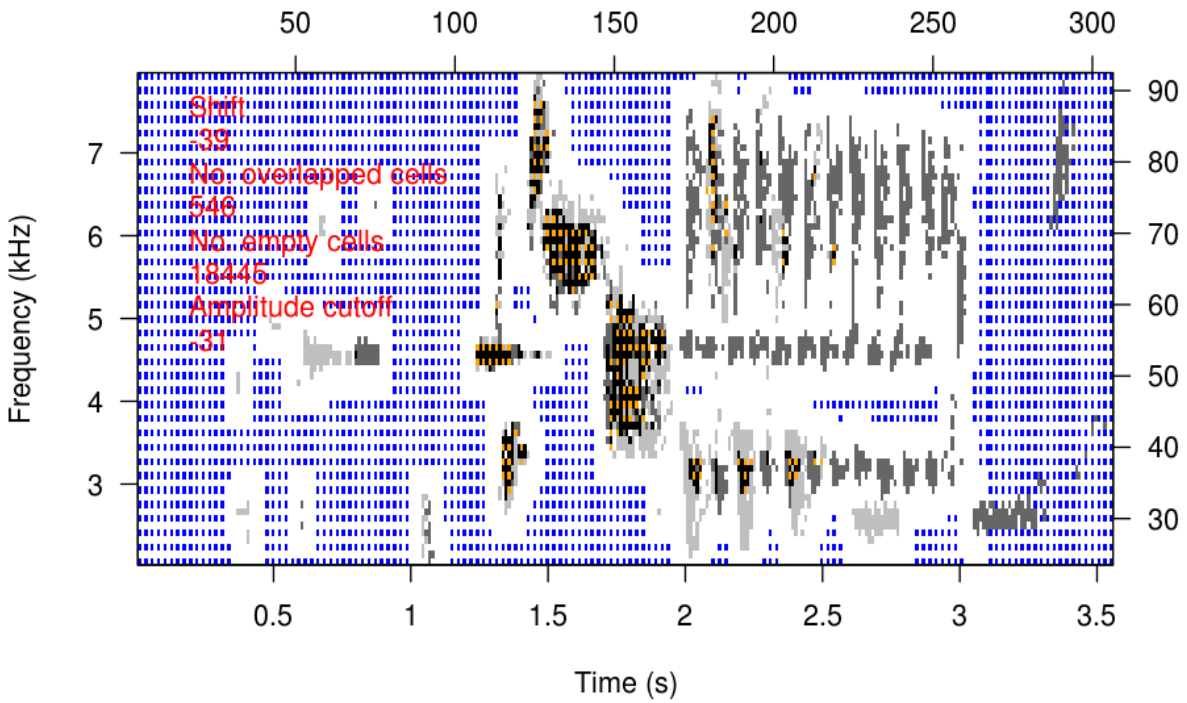


Figure S7.16. Call 3; Automatic selection at a reduced density and with a 4-point buffer.

Combine templates for uninterrupted analysis, adjust score.cutoff, rename them

Templates can be used for binary point matching as soon as they are made, but to scan a survey with multiple templates you must combine them into a list. It is possible to combine templates with multiple FFT parameters into a list, but the FFT will need to be recomputed for each template, which will add several seconds to each pass. Combining the templates will also expedite saving them for future use, either locally or in a database. The combineBinTemplates function is demonstrated below. This process assigns a default score cutoff to all templates. For binary point matching the score is the difference between the mean amplitude of the on points and the mean amplitude of the off points; the score units are decibels (dB).

```
# This call assigns a default score.cutoff for all templates
# Gather templates into a list
BINtemplates<-combineBinTemplates(
BTNW_rect_d100_B,
BTNW_rect_d100_b2_B,
BTNW_rect_d20_b2_B,
BTNW_auto_d80_b2_B)
# Miss one? Use the same function to add it to the list:
BINtemplates<-combineBinTemplates(BINtemplaets,BTNW_click_d100_B)
# Specify a new score.cutoff for each template individually:
BINtemplates<-templateCutoff(
      BINtemplates,score.cutoff=c(
            BTNW_rect_d100_B=9,
            BTNW_rect_d100_b2_B=8.5,
            BTNW_rect_d20_b2_B=9.5,
            BTNW_auto_d80_b2_B=8.5,
            BTNW_click_d100_B=7))
# Rename them too:
BINtemplates<-templateNames(BINtemplates,c(…vector of names…))
```

The print method for this class returns a summary of all templates in the list when called:

```
> BINtemplates
Object of class " binTemplateList "

      containing 5 templates
                                  original.recording sample.rate
BTNW_rect_d100_B    ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
BTNW_rect_d100_b2_B ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
BTNW_rect_d20_b2_B  ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
BTNW_auto_d80_b2_B  ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
BTNW_click_d100_B   ~/Dropbox/LabDemo/Templates/BTNW.wav       24000
                    lower.frequency upper.frequency duration on.points
BTNW_rect_d100_B           3.562500        6.703125     1.98       735
BTNW_rect_d100_b2_B        3.375000        6.703125     1.86       735
BTNW_rect_d20_b2_B         3.281250        6.656250     1.86        80
BTNW_auto_d80_b2_B         3.515625        6.703125     1.96       201
BTNW_click_d100_B          3.609375        6.656250     1.73        71
                    off.points score.cutoff
BTNW_rect_d100_B          5472          9.0
BTNW_rect_d100_b2_B       4639          8.5
BTNW_rect_d20_b2_B         580          9.5
BTNW_auto_d80_b2_B        1232          8.5
BTNW_click_d100_B           81          7.0
```

Save Templates

Save the Correlation Template list to a local disk

The template list can be saved to a local directory with the writeCorTemplates function:

```
> writeCorTemplates(
      templates=CORtemplates,
      dir='C:/Users/jkatz3/Dropbox/LabDemo/WAVclips/Templates')
Template written to file "C:/Users/jkatz3/Dropbox/LabDemo/WAVclips/Templates/BTNWd1.0.ct"
Template written to file "C:/Users/jkatz3/Dropbox/LabDemo/WAVclips/Templates/BTNWpartial.ct"
Template written to file "C:/Users/jkatz3/Dropbox/LabDemo/WAVclips/Templates/BTNWd.8.ct"
Template written to file "C:/Users/jkatz3/Dropbox/LabDemo/WAVclips/Templates/BTNWd.5.ct"
Template written to file "C:/Users/jkatz3/Dropbox/LabDemo/WAVclips/Templates/BTNWd.2.ct"
Template written to file "C:/Users/jkatz3/Dropbox/LabDemo/WAVclips/Templates/BTNWauto.8.ct"
Template written to file "C:/Users/jkatz3/Dropbox/LabDemo/WAVclips/Templates/BTNWauto.2.ct"
```

Save the Binary Point Template list to a local drive with writeBinTemplates

Once the templates have been made they can be saved to a local directory with the writeBinTemplates function:

```
> writeBinTemplates(
      templates=BINtemplates,
      dir='C:/Users/jkatz3/Dropbox/LabDemo/WAVclips/Templates')
Template written to file "C:/Users/jkatz3/Dropbox/LabDemo/WAVclips/Templates/BTNWd1.0BIN.bt"
Template written to file "C:/Users/jkatz3/Dropbox/LabDemo/WAVclips/Templates/BTNWpoint1.0BIN.bt"
Template written to file "C:/Users/jkatz3/Dropbox/LabDemo/WAVclips/Templates/BTNWd.8BIN.bt"
Template written to file "C:/Users/jkatz3/Dropbox/LabDemo/WAVclips/Templates/BTNWauto.5BIN.bt"
```

Upload the Correlation Template list to the database

The entire correlation or binary point template can be uploaded to the database using the function dbUploadTemplates since it usually consists of relatively few sample points compared to a wav file of equal duration. The following example will demonstrate the process on a correlation template, but the process is identical for binary point templates.

Use the args call to see the arguments for the dbUploadTemplates function:

```
> args(dbUploadTemplates)
function (template.L, which.one = NA, db.name = "acoustics",
    uid = "default", pwd = "default", analyst, locationID,
    date.recorded = "", recording.equip = "", species.code,
    ...)
```

The which.one argument allows upload of just a single template in the list rather than the whole list. Leave the default "NA" to send the whole list. The "…" allows additional arguments to be passed to odbcConnect. This function requires that the connection to the database be established in your ODBC manager; if you do not have a database username and password stored in your ODBC manager you may use the uid and pwd arguments to supply them here. The analyst and locationID arguments require the key values from tblPeople.pkPersonID and tblLocation.pkLocationID. The optional recording equipment argument allows you to name the type of recorder used, and the required species code allows you to specify a species code from tblSpecies.fldSpeciesCode. For birds this is the standard four-character BBL codes, but for other species it may be four, six or eight-character codes derived from the latin nomenclature. In all cases the codes must exist in tblSpecies prior to assigning them to a template.

```
# This call demonstrates how to create a vector of species codes, but in this
      case one code could have been used and it would be recycled:
dbUploadTemplates(
      templates=CORtemplates,
      analyst=2,
      locationID=9,
      recording.equip='Sennheisershotgun/Marantz',
      species.code=c('BTNW', 'BTNW', 'BTNW', 'BTNW', 'BTNW'))
# This call demonstrates all arguments to send only one template:
dbUploadTemplates(
      templates=CORtemplates,
      which.one= BTNW_rect_C,
      db.name="acoustics",
      uid="username",
      pwd="sEcurePass2!",
      analyst=2,
      locationID=9,
      date.recorded="2010-05-29",
      recording.equip='SennheiserShotgun/Marantz',
      species.code='BTNW')
```

Building a Template Library and Fine-Tuning Templates

Now your mission is to find more potential templates so you can choose the highest performing one. To do this you will use spectrogram cross correlation and the sccCor function.

Rationally choosing sound clips for your template

The compareTemplates function uses sccCor or binaryPtMatch to collect the score of each potential template against all other potential templates. The compareTemplates function arranges the results into a list of four tables; the first is a list of mean times for the hits that will be used as row names in the rest of the lists, the second is a list of peak times for each template in seconds, the third is a list of peak times for each template in mm:ss.ss, and the fourth is a table of all scores for all templates. This process will be demonstrated using sccCor, but the process is identical for binary point matching if the function binaryPtMatch is used in place of sccCor.
To use compareTemplates run the sccCor function, using each potential template clip as a template. In the following example 23 unique song sparrow example songs are saved to a SOSPtemplates directory. Each is read into R and a template is constructed, and all templates are combined into an object called templates.

```
templates <- makeTemplates(
    wave.L=list(
       s1='E:/users/jkatz3/Desktop/SOSPtemplates/s1.wav',
       s2='E:/users/jkatz3/Desktop/SOSPtemplates/s2.wav',
       s3='E:/users/jkatz3/Desktop/SOSPtemplates/s3.wav',
       s4='E:/users/jkatz3/Desktop/SOSPtemplates/s4.wav',
       s5='E:/users/jkatz3/Desktop/SOSPtemplates/s5.wav',
       s6='E:/users/jkatz3/Desktop/SOSPtemplates/s6.wav',
       s7='E:/users/jkatz3/Desktop/SOSPtemplates/s7.wav',
       s8='E:/users/jkatz3/Desktop/SOSPtemplates/s8.wav',
       s9='E:/users/jkatz3/Desktop/SOSPtemplates/s9.wav',
       s10='E:/users/jkatz3/Desktop/SOSPtemplates/s10.wav',
       s11='E:/users/jkatz3/Desktop/SOSPtemplates/s11.wav',
       s12='E:/users/jkatz3/Desktop/SOSPtemplates/s12.wav',
       s13='E:/users/jkatz3/Desktop/SOSPtemplates/s13.wav',
       s14='E:/users/jkatz3/Desktop/SOSPtemplates/s14.wav',
       s15='E:/users/jkatz3/Desktop/SOSPtemplates/s15.wav',
       s16='E:/users/jkatz3/Desktop/SOSPtemplates/s16.wav',
       s17='E:/users/jkatz3/Desktop/SOSPtemplates/s17.wav',
       s18='E:/users/jkatz3/Desktop/SOSPtemplates/s18.wav',
       s19='E:/users/jkatz3/Desktop/SOSPtemplates/s19.wav',
       s20='E:/users/jkatz3/Desktop/SOSPtemplates/s20.wav',
       s21='E:/users/jkatz3/Desktop/SOSPtemplates/s21.wav',
       s22='E:/users/jkatz3/Desktop/SOSPtemplates/s22.wav',
       s23='E:/users/jkatz3/Desktop/SOSPtemplates/s23.wav'),
    frq.lim.L=list(default=c(1.55,8.96)),
    score.cutoff.L=list(default=0.3)
 )
```

Bind all of these clips together into a single file, and separate each clip by at least 1 second of noise. Add a bit of noise by finding 1-2 seconds of noise, highlighting it in Audacity, and exporting the selection to the SOSPtemplates folder. Then read it into R:

```
noise <- readWave(file='E:/users/jkatz3/Desktop/SOSPtemplates/noise.wav')
s1<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s1.wav')
s2<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s2.wav')
```

```
s3<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s3.wav')
s4<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s4.wav')
s5<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s5.wav')
s6<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s6.wav')
s7<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s7.wav')
s8<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s8.wav')
s9<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s9.wav')
s10<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s10.wav')
s11<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s11.wav')
s12<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s12.wav')
s13<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s13.wav')
s14<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s14.wav')
s15<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s15.wav')
s16<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s16.wav')
s17<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s17.wav')
s18<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s18.wav')
s19<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s19.wav')
s20<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s20.wav')
s21<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s21.wav')
s22<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s22.wav')
s23<-readWave('E:/users/jkatz3/Desktop/SOSPtemplates/s23.wav')
```

and make a single file containing all 23 examples of songs:

```
survey <- bind(noise, s1, noise, s2, noise, s3, noise, s4, noise,
s5, noise, s6, noise, s7, noise, s8, noise, s9, noise, s10, noise, s11,
noise, s12, noise, s13, noise, s14, noise, s15, noise, s16, noise, s17,
noise, s18, noise, s19, noise, s20, noise, s21, noise, s22, noise, s23,
noise)
```

Then run sccCor or binaryPtMatch, assigning the output to an object:

```
scc <- sccCor(survey=survey,templates=templates)
```

and then run findPeaks, assigning the output to an object:

```
pks <- findPeaks(score.obj=scc)
```

followed by compareTemplates, assigning the output to an object:

```
comp <- compareTemplates(pks.L=pks,cutoff=0.3,tol=2.0)
```

The argument for peak grouping tolerance (tol) is useful because it allows various unique song types to reach peak correlation with another song at slightly different times. In this example, by setting tol=2.0, I am willing to call peaks within two seconds of one another as correlations with the same song. The output of compareTemplates is a list of four easy-to-compare matrices:

```
>names(comp)
[1] "times.mean" "times"      "times.mmss" "scores"
```

The matrix "times" has units decimal seconds, identical to the matrix "times.mmss" which has units mm:ss.ss. The matrix "scores" is the one we are most interested in, since it will allow us to compare the score of all the templates. View all matrices at once:

```
Comp
```

or view just the matrix of scores:
```
comp$scores
```

For larger matrices it might be better to save them for viewing in Microsoft Excel:

```
write.csv(comp$scores, 'E:/users/jkatz3/Desktop/SOSPtemplates/tmpltComp.csv'
```

Opening this file in Excel you can see the matrix, with the template names in the column headings and the average peak time in the row names. Because the survey file is a list of all of the example song clips in the same order, the diagonal should be the correlation of each song against itself, which would be 1.00 except in cases where the bandpass filter removes some low or high interference. Each column of this table represents the result of a single template, so the most logical way to read this table is down the columns rather than across the rows.

The columns can also be summarized in R using something like colMeans:

```
colMeans(comp$scores, na.rm=TRUE)
```

and

```
max(colMeans(comp$scores, na.rm=TRUE))
```

After doing this, I see that s10 has the highest mean correlation with all other song examples. Here is the resulting matrix:

	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13	s14	s15	s16	s17	s18	s19	s20	s21	s22	s23
3.2	1.000	0.706	0.573	0.565	0.717	0.626	0.634	0.595	0.586	0.689	0.623	0.706	0.581	0.678	0.636	0.594	0.590	0.695	0.645	0.659	0.629	0.664	0.650
8.8	0.709	0.912	0.636	0.622	0.787	0.683	0.647	0.662	0.694	0.768	0.719	0.805	0.611	0.796	0.677	0.626	0.624	0.804	0.693	0.761	0.696	0.779	0.771
15.0	0.571	0.613	0.869	0.620	0.590	0.625	0.500	0.563	0.670	0.691	0.749	0.584	0.555	0.626	0.540	0.568	0.479	0.620	0.506	0.640	0.544	0.568	0.643
21.7	0.606	0.602	0.633	0.999	0.592	0.631	0.510	0.605	0.620	0.675	0.638	0.591	0.502	0.598	0.554	0.612	0.493	0.588	0.507	0.601	0.554	0.538	0.619
27.8	0.703	0.785	0.600	0.597	0.897	0.648	0.672	0.603	0.651	0.742	0.700	0.793	0.586	0.742	0.712	0.627	0.615	0.816	0.725	0.704	0.669	0.757	0.712
33.7	0.629	0.675	0.633	0.640	0.640	0.948	0.575	0.629	0.652	0.740	0.707	0.672	0.592	0.650	0.637	0.639	0.557	0.646	0.577	0.655	0.592	0.595	0.685
39.0	0.617	0.648	0.547	0.548	0.696	0.594	0.926	0.575	0.526	0.620	0.557	0.654	0.526	0.606	0.636	0.557	0.588	0.676	0.632	0.607	0.600	0.631	0.582
45.0	0.610	0.637	0.591	0.628	0.616	0.641	0.571	0.927	0.630	0.687	0.645	0.640	0.541	0.639	0.594	0.568	0.555	0.627	0.564	0.644	0.549	0.603	0.670
51.0	0.599	0.651	0.656	0.597	0.627	0.643	0.505	0.578	0.920	0.766	0.821	0.609	0.645	0.670	0.516	0.559	0.461	0.632	0.547	0.704	0.545	0.590	0.712
57.6	0.684	0.751	0.713	0.670	0.750	0.737	0.600	0.661	0.772	0.975	0.822	0.726	0.619	0.805	0.612	0.628	0.527	0.734	0.622	0.806	0.635	0.677	0.820
63.4	0.634	0.705	0.729	0.650	0.681	0.687	0.543	0.627	0.828	0.834	0.921	0.671	0.684	0.730	0.575	0.578	0.501	0.695	0.582	0.759	0.591	0.643	0.771
69.1	0.696	0.809	0.610	0.612	0.791	0.679	0.659	0.631	0.647	0.741	0.686	0.933	0.587	0.749	0.732	0.632	0.646	0.801	0.685	0.698	0.672	0.732	0.708
75.3	0.587	0.594	0.573	0.530	0.585	0.602	0.518	0.535	0.648	0.636	0.652	0.565	0.836	0.579	0.536	0.589	0.495	0.582	0.541	0.620	0.534	0.553	0.613
80.6	0.684	0.797	0.644	0.614	0.744	0.658	0.609	0.618	0.708	0.814	0.737	0.745	0.586	0.889	0.627	0.603	0.574	0.776	0.660	0.769	0.666	0.721	0.772
86.2	0.633	0.673	0.544	0.549	0.680	0.624	0.639	0.567	0.540	0.593	0.574	0.702	0.538	0.624	0.871	0.599	0.623	0.668	0.655	0.591	0.631	0.632	0.579
92.1	0.599	0.623	0.586	0.617	0.630	0.633	0.533	0.565	0.563	0.646	0.591	0.621	0.566	0.604	0.611	0.999	0.537	0.602	0.537	0.581	0.536	0.552	0.615
97.3	0.605	0.631	0.510	0.525	0.636	0.581	0.599	0.565	0.528	0.570	0.533	0.654	0.525	0.588	0.633	0.553	0.853	0.619	0.681	0.553	0.575	0.599	0.566
103.3	0.697	0.802	0.632	0.601	0.815	0.649	0.677	0.620	0.659	0.745	0.700	0.797	0.593	0.771	0.668	0.604	0.621	0.921	0.720	0.730	0.697	0.823	0.751
108.8	0.649	0.704	0.524	0.525	0.723	0.579	0.637	0.548	0.562	0.634	0.585	0.683	0.555	0.654	0.655	0.550	0.666	0.706	0.947	0.639	0.628	0.672	0.618
114.9	0.666	0.744	0.660	0.622	NA	0.663	0.606	0.656	0.727	0.815	0.764	0.691	0.623	0.778	0.599	0.583	0.562	0.728	0.622	0.859	0.640	0.707	0.799
120.4	0.636	0.698	0.563	0.568	0.673	0.597	0.599	0.544	0.570	0.646	0.597	0.669	0.546	0.667	0.634	0.541	0.552	0.718	0.648	0.640	0.905	0.659	0.631
126.1	0.670	0.756	0.581	0.557	0.756	0.604	0.632	0.561	0.614	0.688	0.646	0.730	0.565	0.699	0.642	0.556	0.569	0.797	0.688	0.707	0.684	0.817	0.701
131.8	0.638	0.720	0.567	0.607	0.716	0.690	0.572	0.645	0.710	0.727	0.746	0.695	0.621	0.752	0.581	0.617	0.515	0.723	0.597	0.811	0.606	0.693	0.853

```
> colMeans(comp$scores, na.rm=TRUE)
```

s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13	s14	s15	s16	s17	s18	s19	s20	s21	s22	s23
0.657	0.706	0.616	0.611	0.697	0.653	0.607	0.612	0.653	0.715	0.689	0.693	0.591	0.691	0.629	0.608	0.574	0.703	0.634	0.684	0.625	0.661	0.688

```
> max(colMeans(comp$scores, na.rm=TRUE))
[1] 0.715
```

This process could be repeated using various bandpass filter values and/or various amounts of leading and trailing noise.

Revision History

Version #	Date	Revised by	Changes	Justification
0.10	Sept 2012	Jon Katz	Initial draft, as part of Audio detection SOP	
0.20	Dec 2012	Jon Katz	Added additional sections, as part of Audio detection SOP	
0.30	Jan 2013	Geri Tierney, Brian Mitchell	Separated document into separate SOP. Editorial and formatting changes.	
0.31	April 2013	Brian Mitchell, Geri Tierney	Added info to Introduction regarding why we are not using Song Scope, and briefly describes the approach used. Editorial changes.	Response to external review.
1.00	May 2013	Jon Katz, Geri Tierney	Replaced references to Audacity with a new function viewSpec; accepted changes made by BM and GT. Formatting changes.	Audacity is no longer necessary
1.01	May 2013	Brian Mitchell	When changing the sample rate, spectrograms should be spot-checked to ensure they closely match the original.	changeSampRate appears to work well, but testing was limited

SOP 8 – Automated Sound Detection and Classification

Northeast Temperate Network
Version 1.00

Introduction: Read Me First

There are a variety of tools available for automatic detection of species on audio recordings. Among these, perhaps the best known is the Wildlife Acoustics Song Scope platform, which uses a "Hidden Markov Model" algorithm with carefully developed recognizers to detect species on field recordings. After much consideration, we decided not to use Song Scope for the following reasons:

1) Song Scope is a "black box", and it is not clear exactly what the recognition algorithm does.
2) Song Scope recognizers can only be built by many rounds of trial and error, and tweaking numerous parameters. Building recognizers is an art, not a science.
3) Song Scope is not suitable for long term monitoring since regular software updates alter the recognition algorithm and require complete reanalysis of all prior data to ensure consistency.
4) Song Scope is expensive, especially for a program intended to run in a distributed fashion with many people running analyses.

NETN staff and cooperators decided that the best approach would be to use simple algorithms (spectral cross correlation and binary point matching). While these algorithms are perhaps not as accurate as the latest software, they are easy to explain and visualize, have many fewer parameters to worry about when trying to build templates, and have been shown to be accurate for identifying many species. The approach can also be implemented on a free, widely used platform (R), and because the basic algorithms are not being changed over time, old data does not need to be reanalyzed unless a new species template is developed. The R platform and package we have developed definitely has a learning curve, but so does the process of building recognizers in Song Scope.

This SOP describes wildlife recording file management, the use of R for extracting sound events from the recordings (turning digital sound files into ecological data), and archiving sound events. Sound events from birds, frogs and other taxa are detected and classified using spectrogram cross correlation and/or binary point matching. The resulting dataset is a times series of phenophase detections. SOP 7 – Acoustic Template Creation describes the process of developing templates used in this SOP.

Overview of full data collection and analysis process:

1. Determine the survey schedule and number of sites to monitor (see SOP 2 - Site Selection and Set Up and SOP 6 - Deployment and Maintenance of Autonomous Recording Units).
2. Purchase or build suitable recorders, batteries, and recording media (see SOP 5 - Building an Autonomous Recording Unit and SOP 6).
3. Set up a computer workstation to perform the sound processing, purchase sufficient local disk storage or network disk storage (see SOP 11 - Data Management and QA/QC).

4. Construct a MySQL database and local file system to store recordings and/or results (herein and Appendix S8.A and S8.B; discuss with NETN data manager).
5. Determine maintenance interval based on survey schedule and battery and media capacity (see SOP 6).
6. Install the recorders (see SOP 6).
7. Perform battery and media refreshes at established intervals (see SOP 6).
8. Convert recordings to wav format (herein).
9. Locate suitable template songs in the survey recordings, or record them with a directional microphone, or purchase them from the McCaulay Library of Natural Sounds (discuss with NETN; procedures outlined in SOP 7 - Acoustic Template Creation).
10. Use the R package to convert recordings to environmental data (herein)
11. Save csv files or upload results to the database (or both) (herein).
12. Archive the surveys or events (herein).
13. Optional: Human observer verifies the results (discuss with NETN; herein).

Software Programs Used

Sound detection is performed within R, "a freely available language and environment for statistical computing and graphics" which can be downloaded from the Comprehensive R Archive Network (*http://cran.r-project.org/*).

Before using R for spectrogram cross correlation or binary point matching, add these packages[1] to your R library:

1. tuneR
2. plyr
3. RODBC (for connecting R to a database)
4. seewave (optional for displaying spectrograms in R; has dependencies rgl, rpanel, fftw; see http://rug.mnhn.fr/seewave/inst.html for solutions to known installation issues)

See Appendix S8.C for instructions on downloading R and selected packages.
If recording mp3 files it is sometimes necessary to set the recorder to make several long files each day and then extract short surveys from those longer recordings. Package monitoR has a function that calls the software mp3splt, which can be downloaded from http://mp3splt.sourceforge.net/mp3splt_page/home.php. Installation options are available for any operating system. An advantage to this software is that it does not decode and re-encode the mp3 files to split them, so no audio quality is sacrificed.

[1] A package is a set of functions that runs in R.

Terminology

Bandpass filter: An audio filter that trims frequency data from above and below the frequency band that is allowed to "pass" through. In the digital implementation here, we specify a minimum and maximum frequency that we want to pass through and all frequencies below the minimum and above the maximum are discarded.

Binary point matching: A method for sound detection in which the acoustic template is converted to a matrix of "on" and "off" cells. The mean amplitude (in decibels) of the corresponding "on" points at each time interval in the survey is compared to the mean amplitude of the corresponding "off" points. The user specifies a minimum acceptable difference between the two values to limit the results, and local maximum-difference values above the minimum value identify events.

MP3: A "lossy" compression file format engineered to preserve the most audible human speech frequencies. The compression process has a number of components, and the degree of information loss is determined by how much information must be trimmed to meet the target file size per second (minimum size is 128kbps). MP3 files are low-pass filtered above the threshold of human hearing, and occasionally low amplitude frequency data are discarded if they occur simultaneously with high amplitude frequencies. MP3 files save considerable storage space versus uncompressed files, but obligatory decompression time can be substantial.

Spectrogram cross correlation: A method for seeking a known template in a survey consisting of unknown songs. The correlation of amplitude values in the FFT template matrix to a matrix in the survey is measured using the Pearson method. The survey matrix then shifts one time bin and the correlation to the template is measured again. The user specifies a minimum Pearson score, and local maximum scores identify events.

Survey: A recording that will be searched for the template. Must be a WAV or MP3 file, and must be longer than the template.

Template: A recorded song example which will provide the "search image" for the computer. Must be a WAV or MP3 file. A template may differ from a simple song clip by retaining bandpass filter values and score cutoff values.

WAC: The Wildlife Acoustics proprietary compression format. Use of this format is restricted to Wildlife Acoustic's Song Meter recording units. These units are the data collection standard due to their flexible timed recording, high storage capacity, ultrasonic recording options, data-logging and GPS integration, and weatherproofing. WAC files must be converted to WAV files for use in the R environment using Wildlife Acoustics conversion software.

WAV: An uncompressed linear PCM audio file format owned by Microsoft that is in widespread use sufficient to be considered cross-platform. As a result WAV files are playable on nearly all devices.

Data Management

This protocol outlines two methods of data management. Local data management relies on the analyst to name and file comma-separated values (csv) input and output documents, while MySQL database management automates this process in a relational database. There are several advantages to the MySQL database, including 1) reduction in file management errors, 2) ability to have multiple users access the same database, and 3) reduction in analyst time dedicated to data organization tasks. Setup time should be minimal as a database schema is attached to this document in Appendix S8.B. NETN plans to use a database implementation rather than local data management. Contact the NETN database manager for access to the database.

A relational database consists of a set of tables that relate, or link to, each other. Several naming conventions help distinguish tables in the database from the fields (columns) that compose them. Tables begin with the prefix tbl, followed by a word that describes the content of the table. The fields also begin with prefixes that include pk for primary key—a value unique to each record in the table, fk for foreign key—a value that refers to the primary key in another table, and fld, which indicates that the field stores data. Each table is dedicated to storing information about only one aspect of the data. For example, a table called tblPerson stores information about people involved in the acoustic monitoring program. These may include people who deploy and operate recording devices, people who run analyses, etc. A table called tblLocation stores information about the locations in which acoustic recordings were made, including latitude and longitude, the location name, and whether the location is the location of a monitoring site, or whether the location is a place where only a template has been recorded. The table called tblResult stores the results of the analysis.

The tables required to create a database compatible with this package are listed below. A full description of the database, including an Entity-Relationship diagram and full schema, are in Appendices S8.A and S8.B.

	TABLE NAME	DESCRIPTION
1.	tblCard	Stores information about memory cards.
2.	tblCardRecorder	Tracks which surveys are recorded by which recorders.
3.	tblRecorder	Stores information about recording units.
4.	tblLocation	Stores information about all locations in the project.
5.	tblSurvey	Stores attributes of the survey recording.
6.	tblTemplate	Stores information about all types of templates used in the project.
7.	tblResult	Stores the results of findPeaks().
8.	tblSpecies	Stores information about the target species.
9.	tlbArchive	For archiving sound clips extracted from surveys.
10.	tblPerson	Stores the names of people involved in the monitoring project.
11.	tblPersonContact	Stores contact information for all people in tblPeople.
12.	tblOrganization	Identifies the primary investigative organization.
13.	tblProgram	Stores the names of monitoring programs of each organization.
14.	tbProject	Stores names of monitoring projects in each program.
15.	tblPriors	Stores priors for Bayesian updating.

File management

The process of retrieving and analyzing environmental acoustic data involves a large number of audio files; this SOP describes a system for managing and organizing these files. Set up the following file directories on your storage drive. You will need these directories regardless of whether you use a database.

- A main folder called Acoustics
- Nested within Acoustics are six folders:
    - Recordings (for temporarily holding files that are not wav or mp3 files, such as Wildlife Acoustics' wac files)
    - Surveys (for holding files that are ready for analysis, including wav or mp3 files).
    - Templates (for storing templates)
    - Results (for storing results).
    - Archives (for storing clips of the original recordings for historic or verification purposes)

Within the Surveys directory, create a directory for each location that you are monitoring. For example, all recordings collected at SARA (e.g. SARA0001, SARA0002, SARA0003, SARA0004) are stored in a folder named SARA. Note that each site is identified by the four-digit number assigned to the site by USA-NPN, and thus the site numbers will not be as simple or sequential as those shown in this example. If you are using the MySQL database, the location folder names should match those in tblLocation .fldLocationName.

Within the Templates directory, create a directory for each species that you are monitoring. Use a coding scheme that allows you to rapidly find what you are looking for. For example, three templates for birds can be named SOSP (for Song Sparrow), BTNW (Black-throated Green Warbler), and OVEN (Ovenbird). If you are using the MySQL database the folder names should match the field tblSpecies.fldSpeciesCode.

Other folders (directories) will be created by R as you work through the analysis.
For long-term monitoring projects these directories may be created on separate drives or across a RAID system (redundant array of independent disks). All data must be redundantly backed up. While storage on a raid does place the data in two locations a separate backup drive is also needed, since failure of a RAID controller can prevent access to all data on the RAID system.

Download Recordings From SD Card

R becomes involved in the analysis process when an SD card (or other media device) is plugged into a computer to download the recordings. The first step of moving the recordings from the card to the computer is handled by the fileCopyRename function. The procedure varies depending on whether the survey recordings are in wac format versus wav or mp3 format.
The database will enforce associations between the results and the surveys, locations, cards, recorders, and analysts. The connection to the survey will be automatic, but the connection to the other attributes of the monitoring program requires that the user specify the card and recorder that the results stem from, by identifying the value from tblCardRecorder.pkCardRecorderID. Therefore, the value for the CardRecorderID will need to be known when downloading surveys from the SD cards. The simplest way to look this up is to use the query that downloads a table of

relevant CardRecorderIDs. This query will download all CardRecorderIDs for specified sites within a specified time window.

```
# Download a table of CardRecorderIDs that correspond to site and time
associations
crlocs<-dbDownloadCardRecorderID(
      db.name='UVMacoustics',
      date.deployed='0000-00-00',
      date.collected='0000-00-00',
      loc.prefix=c('MABI01','MABI02','MABI03','MABI04'))
crlocs
```

Song Meter files

Song Meter units record in wac format. For these files, use the fileCopyRename function to copy the files from the SD card to a holding folder, from which you can then convert them to wav. The function fileCopyRename has 11 arguments, which you can view using the args function:

```
> args(fileCopyRename)
function (from = ".", to = ".", csv.dir = to, csv.name = NA,
   loc.prefix, ext, CardRecorderID = NA, kaleidoscope = TRUE,
    split.channels = FALSE, metadata.only = FALSE, parallel = FALSE)
```

Soon you will need to convert the wac files to wav files using Wildlife Acoustic's Kaleidoscope software; if you will be splitting the channels (e.g. if you have an ultrasonic mic in the right channel and a standard mic in the right channel) you should set the split.channel=TRUE. The command should be:

```
surveydata<-fileCopyRename(
      from='C:/Users/jkatz3/Dropbox/UVMacoustics/Analysis/Recordings',
      to='C:/Users/jkatz3/Desktop/TestFolder',
      csv.dir='C:/Users/jkatz3/Desktop/MetadataFolder',
      loc.prefix='MABI02',ext='wac',CardRecorderID=1, split.channels=TRUE)
```

You can leave the kaleidoscope, metadata.only, and parallel options with their default values for now. During the copy process all files will be renamed the specified six-digit location prefix followed by the original file's date modified, including the time zone. The new file names will be:

PARK#### YYYY-MM-DD HHMMSS TZX.wac

A csv will be produced containing all of the new wac file names and original dates modified, and it will be saved in the directory specified in the command. The name of the csv file will default to the location prefix followed by the time the files were copied, but you can use the argument csv.name to specify a custom name if you prefer. In the csv, the date modified on the wac files matches the original of the files still on the card, but the files will display a new date created—these are copies of the original files, but not the original files. Although they are newly created, no samples have been added or removed from the data portion of the file. The survey names in the csv will not match the actual file names exactly. Kaleidoscope will change the file name during file conversion, so the survey name in the csv will match the file name after conversion to wav format.

Specifying a CardRecorderID (from tblCardRecorder.pkCardRecorderID) completes the link that joins each survey file to both the recorder that recorded it and the card it was recorded to. Failure to specify this value will not cause the database to reject the metadata upload, but it will prevent the user from making queries that rely on that connection in the future.

If using a database, the next step is to upload this metadata to the database to keep it safe. Refer to that section in the upload to database section.

Next, convert the wac files to wav files. This conversion should be done promptly to ensure that the database matches the actual files. For this step it is necessary to leave R and use software provided by Wildlife Acoustics. The application Kaleidoscope performs this step in bulk, and it offers the option to split the tracks and/or cut the file into shorter length segments. If one channel is dedicated to ultrasonic recording it will be necessary to split the channels, but only the right channel will be logged in the database or csv file.

After converting the files to wav call fileCopyRename again to move the files to the survey folder, but this time set metadata.only = TRUE to turn off the file renaming.

```
surveymetadata<-fileCopyRename( from='C:/Users/jkatz3/Desktop/TestFolder',
      to='C:/Users/jkatz3/Desktop/Surveys',
      csv.dir='C:/Users/jkatz3/Desktop/MetadataFolder',
      loc.prefix='MABI02',ext='wav',metadata.only=TRUE)
```

Olympus units

Olympus units record in mp3 or wav[2] format. They are currently limited to three scheduled recording events per day; to collect more than three surveys per day they should be set to record as many as 24 hours per day (see SOP 6 - Deployment and Maintenance of Autonomous Recording Units) and then individual surveys of a fixed duration are subsampled from each hour of the recording. Function mp3Subsamp is used to extract short surveys from continuous recordings, and it simultaneously moves survey files directly to the survey folder, returns the same metadata as fileCopyRename does for wav files, and renames the new surveys according to their location prefix and the time and date they occurred. There is no file-type conversion between copying the survey files and scanning them with the detector functions. Function mp3Subsamp relies on third-party software to split the mp3 files without decoding and re-encoding them. Before using this function, the zip file or the installer must be downloaded from http://mp3splt.sourceforge.net/mp3splt_page/home.php. Note that no administrator permissions are required to install from the zip file.

To use mp3Subsamp a survey duration (in seconds) must be specified, as well as the number of minutes between surveys, the directory where the recordings currently are, and the directory where they should be saved to when extracted. The function also requires the bitrate of the

[2] The Olympus model NETN typically uses does not have a .wav option, but some Olympus models do.

recording, the sample rate, and the number of channels to be specified in the call. The default settings of 600 seconds (ten minutes) from the top of every hour, recorded at 128 kbps in stereo at 44100 Hz match the setup described in SOP 6.

```
surveydata<-mp3Subsamp(
      from='C:/Users/jkatz3/Dropbox/UVMacoustics/Analysis/Recordings',
      to='C:/Users/jkatz3/Desktop/TestFolder',
      csv.dir='C:/Users/jkatz3/Desktop/MetadataFolder',
      loc.prefix='MABI02',ext='mp3',CardRecorderID=1, duration=600,
      mins.between=50, index='hour', kbps=128, samp.rate=44100, channels=2)
```

The index argument can be changed to `'time0'` to subsample starting from the first 10 minutes of each recording rather than the top of each hour. Files will be renamed to a user-specified six-digit location prefix followed by the original file's date modified, including the time zone. The name will be:

PARK#### YYYY-MM-DD HHMMSS TZX.mp3

Description of arguments to mp3Subsamp

1. **CardRecorderID** This is the unique number assigned to each combination of card, recorder, and date deployed in the field. Example: 101
2. **ext** This is the file type of the recording: wac, wav, or mp3. Example: 'wac' [include the apostrophes as this is a text string].
3. **loc.prefix** This is the eight-character site id. E.g.: 'LOCA0001' [include the apostrophes as this is a text string]. The first four characters are the NPS acronym corresponding to the park of deployment (e.g., ACAD), and the next four characters are the four-digit number assigned by USA-NPN for the site of deployment.
4. **from** This is the location of recordings on the SD card. This is usually not in the top directory of the card, but may be in a subdirectory named 'Data' or 'Recordings'. Example: 'F:// Recordings' [include the apostrophes as this is a text string].
5. **to** This is the location of the directory to move files to. Example: 'C://Acoustics/Surveys/' [include the apostrophes as this is a text string].
6. **csv.dir** This is the location of the directory that will store the csv file that summarizes the file information. This defaults to the destination folder for the recordings/surveys, or you can specify a new directory such as: 'C://Acoustics/Surveys/' [include the apostrophes as this is a text string].
7. **csv.name** This is the name of the csv file that summarizes the file information. If you do not choose a name the assigned name will be the loc.prefix and the date the files were copied in a YYYY-MM-DD format: 'LOCA0001 20121109.csv'.
8. **duration** This is the duration in seconds of the surveys to extract.
9. **mins.between** This identifies the number of minutes to leave between each survey.
10. **index** This can be set to 'hour' or 'time0'. Hour extracts surveys from the top of each hour, and time0 extracts surveys starting at the beginning of the recording.
11. **kbps** Most mp3 files are compressed to a constant bitrate. SOP 6 - Deployment and Maintenance of Autonomous Recording Units, defines the bitrate to select as 128 kbps.
12. **samp.rate** The sampling rate of the mp3 file. The Olympus recorder in SOP 5 - Building an Autonomous Recording Unit , defaults to 44100 Hz.
13. **channels** stereo=2, mono=1. The Olympus recorder in SOP 5 can only record in stereo.

Upload survey metadata to the database only once, using the dbUploadSurvey function, and setting the argument update=FALSE. View the arguments for this function using the args command:

```
> args(dbUploadSurvey)
function (db.name = "acoustics", uid = "default", pwd = "default", surveys,
      update.query = FALSE, ...)
```

The "…" allow the user to add additional arguments to odbcConnect. If you have set up your ODBC connector to save your database username and password, the initial call will look like this:

```
dbUploadSurvey(db.name='acoustics', surveys=surveydata)
```

If you opt to enter that information at each use you can specify that information in the call:

```
dbUploadSurvey(db.name='acoustics', uid='dbuser', pwd='#sEcurePaSs1',
      surveys=surveydata)
```

A successful upload will return the time taken to run the insert query, and an unsuccessful upload will return the error message provided by the MySQL server.

Read Saved Templates

Read correlation templates from the local disk

Use the function readCorTemplates to read one or several templates. Specify which templates to read in, the directory in which they reside, and the name of the object they will be assigned to.

```
CORtemplates<-readCorTemplates(
      files=c(
            BTNW_rect_C=BTNW_rect_C,
            BTNW_rect_d50_C=BTNW_rect_d50_C,
            BTNW_auto_d80_C=BTNW_auto_d80_C,
            BTNW_line_d100_C=BTNW_line_d100_C,
            BTNW_click_allNotes_C=BTNW_click_allNotes_C),
      dir='C:/Users/jkatz3/Dropbox/LabDemo/Templates)
```

Another method would be to read in all correlation templates in the directory, in which case you need only specify the directory.

```
CORtemplates<-readCorTemplates(
      dir=' C:/Users/jkatz3/Dropbox/LabDemo/Templates/MABI2_A_062510.wav ')
```

The resulting object is a template list ready to be used for correlation analysis.

Read binary point templates from the local disk

```
BINtemplates<-readBinTemplates(
      files=c(
            BTNWd1.0='BTNWd1.0.ct'
            BTNWpartial='BTNWpartial.ct'
```

```
            BTNWd.8='BTNWd.8.ct'
            BTNWd.5='BTNWd.5.ct'
            BTNWd.2='BTNWd.2.ct'
            BTNWauto.8='BTNWauto.8.ct'
            BTNWauto.2='BTNWauto.2.ct'),
      dir='C:/Users/jkatz3/Dropbox/LabDemo/Templates',
      parallel=FALSE)
BINtemplates<-readBinTemplates(
      dir=' C:/Users/jkatz3/Dropbox/LabDemo/Templates/MABI2_A_062510.wav ',
      parallel=FALSE)
```

Download binary point and correlation templates from the database

If your templates are stored in the database, download them with the dbDownloadTemplates function. There are several approaches to this. To download all templates for correlation analysis, specify either the file extension (ct or bt) or the label COR or BIN in the by.type argument. This function demands that all templates entering a list have the same FFT parameters.

```
# Download all correlation templates from the database with the appropriate
FFT parameters
CORtemplates<-dbDownloadTemplates(
      db.name='acoustics',
      by.type='ct',
      FFTwl=512,
      FFTovlp=50)
```

To download specific templates by name, specify them by entering a vector of names in the template.group argument and setting the by.cat argument to “names”:

```
# Download just a few correlation templates, specifying them by template name
CORtemplates<-dbDownloadTemplates(
      db.name='acoustics',
      by.type='ct',
      FFTwl=1024,
      FFTovlp=50,
      by.cat='names',
      template.group=c('BTNW_d05_Buff3_ovlp50_wl1024_BIN'))
```

Or to download all templates for a particular species, specify them by entering a vector of species codes in the template.group argument and setting the by.cat argument to “species”:

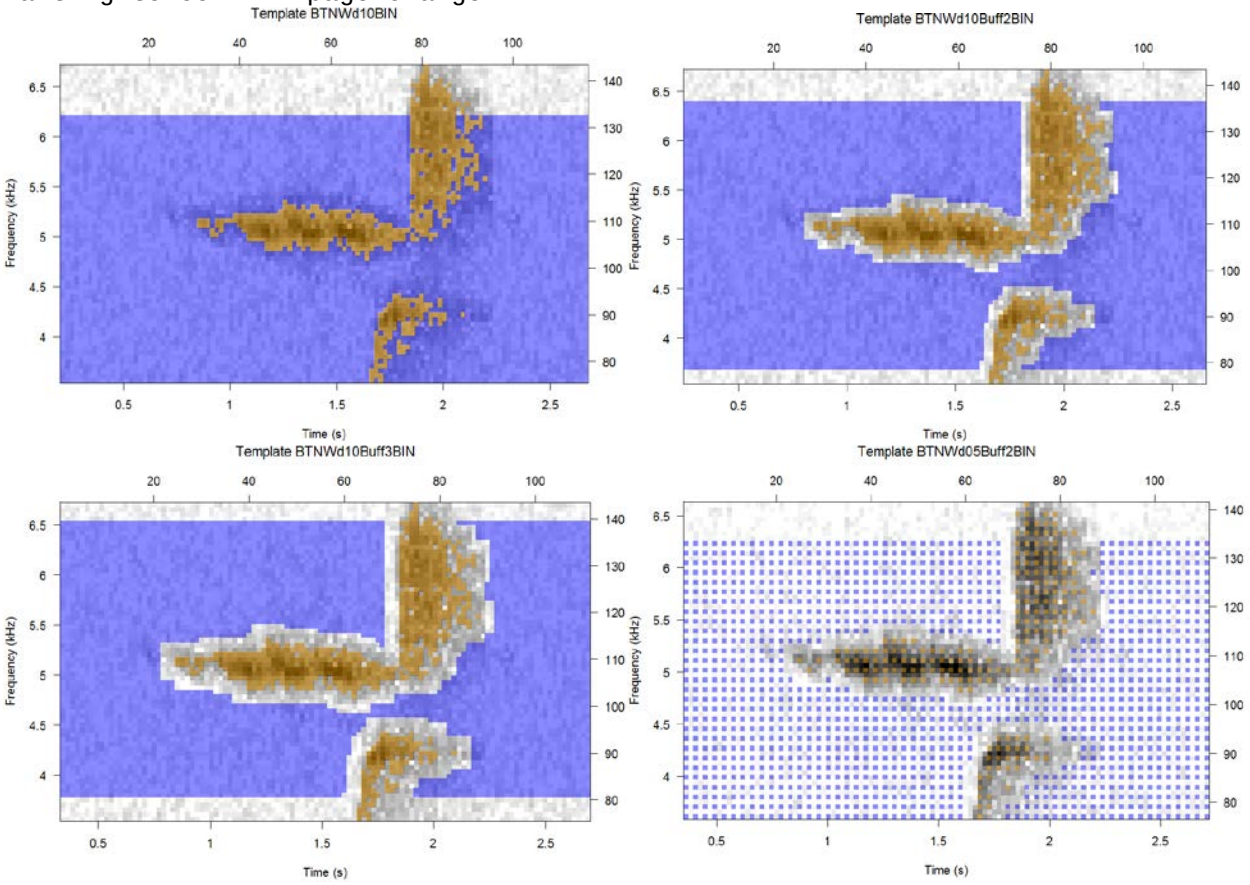
```
# Download just a few correlation templates, specifying them by species code
CORtemplates<-odbcDownloadTemplates(
      by.type='ct',
      FFTwl=1024,
      FFTovlp=50,
      by.cat='species',
      template.group=c(BTNW,'SOSP'))
```

The resulting object is a template list ready to be used in the appropriate analysis, either spectrogram cross-correlation or binary point matching.

View previously constructed templates

View the templates in a template list simply by using the plot method for template lists. After entering the plot(*yourtemplate*) command, pressing return will advance to the next template in the list. The example below uses this function to illustrate how the buffer argument can be used to effectively separate the on points from the off points in a binaryPtMatch analysis.

```
> plot(BINtemplates)
Waiting to confirm page change...
Waiting to confirm page change...
Waiting to confirm page change...
```



FigureS8.1. The off points in the template should ideally be restricted to just noise, but in the top left image with no buffer it includes some lower-amplitude signal as well. This may inhibit the ability of binaryPtMatch to distinguish between signal and noise by reducing the difference between the mean on point amplitude and mean off point amplitude. A buffer of 2 (top right) pushes most of the off points to the edge of the signal, and a buffer of 3 (bottom left) satisfactorily restricts the off points to just noise. In this example, increasing the buffer above 4 will allow for the 'wiggle' that may accommodate subtle variations in song timing or frequency between individual birds. The bottom right image illustrates a template with a buffer of 2 and a density of 0.5.

Analysis of Audio Files

The next step is to analyze a survey file with one or more templates to determine if specific target species occur in the survey. This process searches a long recording (survey) for one or more templates of either the same or different species. The template search process is sequential, so searching for the second template will begin only after the first one finishes. The score cutoff can be adjusted at this time if necessary. The advantages of searching for multiple templates at once are: transfer of coding time to the front allowing for unattended computing, the option to directly compare multiple templates or template settings, and the option to use the compareTemplates function to rationally choose an optimal template.

Spectrogram cross correlation will be used for detection of most species; however binary point matching may be useful in some cases.

Due to limitations with R's system interface capabilities, sccCor and binaryPtMatch can only take advantage of parallel processing on non-Windows operating systems; only set parallel=TRUE on Linux or MacOS. Windows users can run multiple instances of R to achieve a similar effect, with each instance scanning a different survey. Run only as many instances as CPU cores available.

Spectrogram Cross Correlation

First, load the templates into the R workspace. The function to do this varies depending on where your templates are stored.

The function sccCor performs the spectrogram cross correlation. It uses the FFT[3] parameters specified by the template. If using Linux or MacOS you can set parallel=TRUE for faster processing. Speed should increase approximately linearly with an increase in the number of CPU cores.[4]

```
scc<-sccCor(
      survey='C:/Acoustics/Surveys/MABI2_A_062510.wav',
      template.L=CORtemplates,parallel=FALSE)
> scc
A templateScores object
Survey information
Wave Object
        Number of Samples:      14571815
        Duration (seconds):     607.16
        Samplingrate (Hertz):   24000
        Channels (Mono/Stereo): Mono
        Bit (8/16/24/32):       16
Template information
```

[3] Fast Fourier Transformation
[4] Most NPS computers operate on the Windows Operating System, but some parks may have other machines.

```
7 sccCor templates
                                              original.recording lower.frequency
BTNWd1.0    C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav           3.656
BTNWpartial C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav           4.547
BTNWd.8     C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav           3.609
BTNWd.5     C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav           3.609
BTNWd.2     C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav           3.703
BTNWauto.8  C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav           2.016
BTNWauto.2  C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav           2.016
            upper.frequency lower.amp upper.amp duration n.points score.cutoff
BTNWd1.0              6.797   -86.965     0.000    2.539     8160          0.4
BTNWpartial           8.438   -92.442     0.000    2.581     6014          0.4
BTNWd.8               6.703   -92.442    -2.098    2.603     2108          0.4
BTNWd.5               6.797   -82.282    -2.098    2.560     2135          0.4
BTNWd.2               6.656   -83.995    -5.877    2.560      902          0.4
BTNWauto.8            8.953   -92.442    -2.098    2.773     4950          0.4
BTNWauto.2            8.906   -83.995    -5.877    2.752     2200          0.4

Score information

            min.score max.score n.scores
BTNWd1.0        -0.29      0.79    28340
BTNWpartial     -0.16      0.81    28338
BTNWd.8         -0.32      0.78    28337
BTNWd.5         -0.31      0.79    28339
BTNWd.2         -0.34      0.79    28339
BTNWauto.8      -0.15      0.65    28329
BTNWauto.2      -0.16      0.65    28330
```

The next step is to identify events within the score list using the cutoff threshold stored in the template. This is done with the findPeaks function.

Binary Point Matching

In some cases, Binary Point Matching may be a better method than Spectrogram Cross Correlation. First, load the templates into the R workspace. The function to do this will vary depending on where your templates are stored.

The function binaryPtMatch performs the point match detection and classification. By default it uses a window length of 512 with an overlap of 0. If using Linux or MacOS you can set parallel=TRUE for faster processing. Speed should increase linearly with an increase in the number of cpu cores.

Detection of some calls may be improved by changing the FFT window length, FFT overlap, or FFT window function. If you need to do this the binaryPtMatch function will pass the argument to spectro:

```
> scores<-binaryPtMatch(
      survey='C:/Users/jkatz3/Dropbox/LabDemo/Surveys/MABI2_A_062510.wav',
      template.L=BINtemplates,parallel=FALSE)
> scores
A templateScores object
Survey information
Wave Object
        Number of Samples:      14571815
        Duration (seconds):     607.16
        Samplingrate (Hertz):   24000
```

```
        Channels (Mono/Stereo): Mono
        Bit (8/16/24/32):       16
Template information
4 binary templates
                                                original.recording
BTNWd1.0BIN     C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav
BTNWpoint1.0BIN C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav
BTNWd.8BIN      C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav
BTNWauto.5BIN   C:/Users/jkatz3/Dropbox/LabDemo/Templates/BTNW.wav
                lower.frequency upper.frequency duration on.points off.points
BTNWd1.0BIN            3.562500        6.703125     2.39       735       6282
BTNWpoint1.0BIN        2.671875        8.156250     2.37        25         73
BTNWd.8BIN             3.515625        6.609375     2.47       192       1756
BTNWauto.5BIN          2.015625        8.953125     2.77       192       4566
                score.cutoff
BTNWd1.0BIN                9
BTNWpoint1.0BIN            9
BTNWd.8BIN                 9
BTNWauto.5BIN              9
Score information
                min.score max.score n.scores
BTNWd1.0BIN         -8.44     28.75    28348
BTNWpoint1.0BIN     -8.85     39.17    28349
BTNWd.8BIN          -9.46     28.62    28344
BTNWauto.5BIN       -7.62     30.49    28330
```

The list of scores is probably very long, as there will be one record for each time bin, minus the template length.

The next step is to identify events within the score list and specify a cutoff threshold, which is done with the findPeaks function.

Event analysis

The function findPeaks identifies events within the correlation and binary point match scores, and returns a list of event times and peak event scores. findPeaks is used for both sccCor and binaryPtMatch. The following example displays results from sccCor, but the process is identical for both methods. This function can use the cutoff value in the template, or you can specify a new score cutoff.

To view score cutoff thresholds for a template use templateCutoff:

```
> templateCutoff(BINtemplates)
BTNWd1.0BIN BTNWpoint1.0BIN   BTNWd.8BIN  BTNWauto.5BIN
9           9                 9           9
```

To specify new score cutoff thresholds for a template use templateCutoff again:

```
> templateCutoff(BINtemplates)<-c(9,10,10,13,10,12,14)
```

The only required argument for findPeaks is score.obj (the output from sccCor). As usual, assign the output to an object in R:

```
> CORpks<-findPeaks(score.obj=scc,parallel=FALSE)
```

```
Done with BTNWd1.0
Done with BTNWpartial
Done with BTNWd.8
Done with BTNWd.5
Done with BTNWd.2
Done with BTNWauto.8
Done with BTNWauto.2
Done
```

The output is an object of class "foundPeaks", which contains a list of lists for each template. The first list for each template contains a data frame of all correlation peaks (pks), the second list contains a data frame of peaks greater than the specified cutoff (hits), and the third is a one-line summary of the first two. A summary of the results can be viewed by typing in the name of the object they were assigned to:

```
> CORpks
A foundPeaks object
7 templates

            n.peaks n.hits min.score max.score
BTNWd1.0        209     19  -0.00578     0.789
BTNWpartial     192     22   0.03410     0.806
BTNWd.8         218     18   0.01300     0.783
BTNWd.5         218     19   0.01370     0.786
BTNWd.2         213     20   0.04950     0.785
BTNWauto.8      187     15   0.03310     0.647
BTNWauto.2      193     14   0.04490     0.648
```

Verifying Results

A subset of the data is manually verified for proper identifications. This may be performed under the direction of NETN staff, rather than by park coordinators.
Verifying the results serves three purposes:

1. Evaluate the automatic score.cutoff used when scanning surveys.
2. Observe of patterns of misidentification of templates
3. Construct hit densities for likelihood analysis

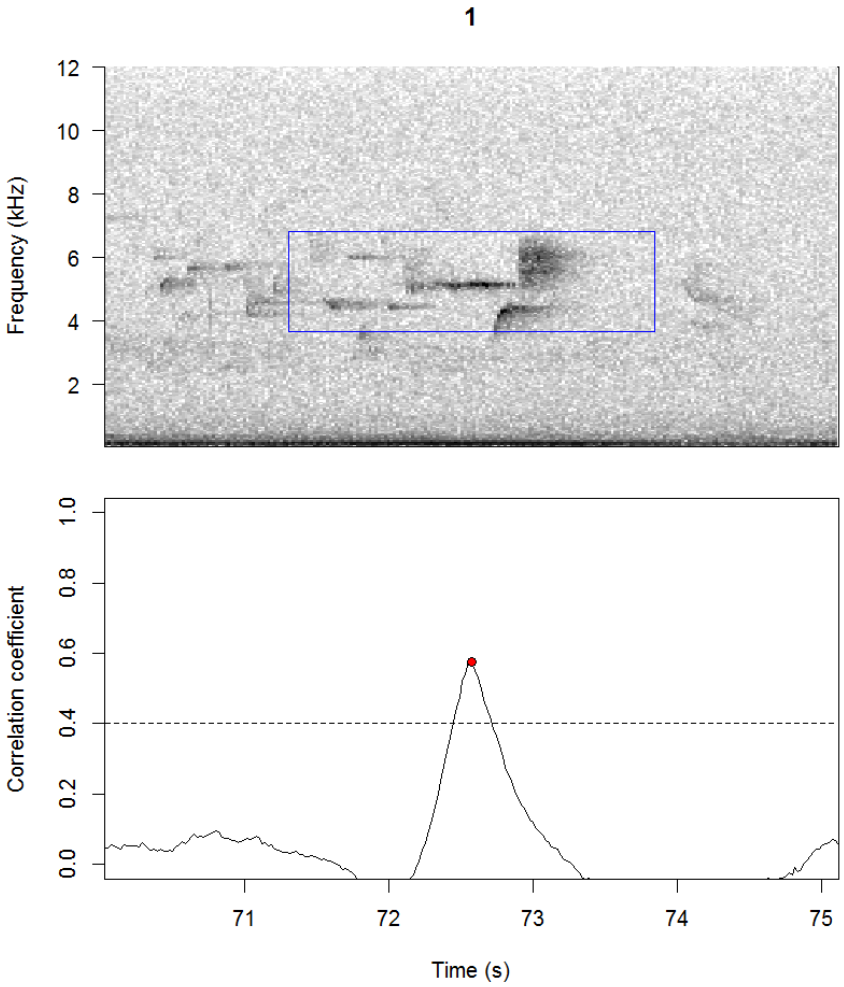
The three ways of verifying the detections and classifications are looking at spectrograms while listening to individual hits within the hits list using the showPeaks function, viewing annotated spectrograms of the survey using the SCTPlot function, and viewing spectrograms of all hits side-by-side using the collapseClips function.

Verifying individual hits via spectrograms and playback

The arguments for the showPeaks function include scc, pks.L, and which.one; these feed the data in from sccCor and findPeaks and identify the template to be verified. The argument t.lim allows just a portion of the hits to be verified, by specifying the start and end times in seconds. The flim argument customizes the spectrogram y axis. The verify argument controls the interactive verification process (setting it to FALSE allows you to quickly flip through spectrograms of the hits without verifying) and the player argument identifies the WAV player that will receive the play commands. Spectrogram cross-correlation scores will range between 0 and 1, so set the

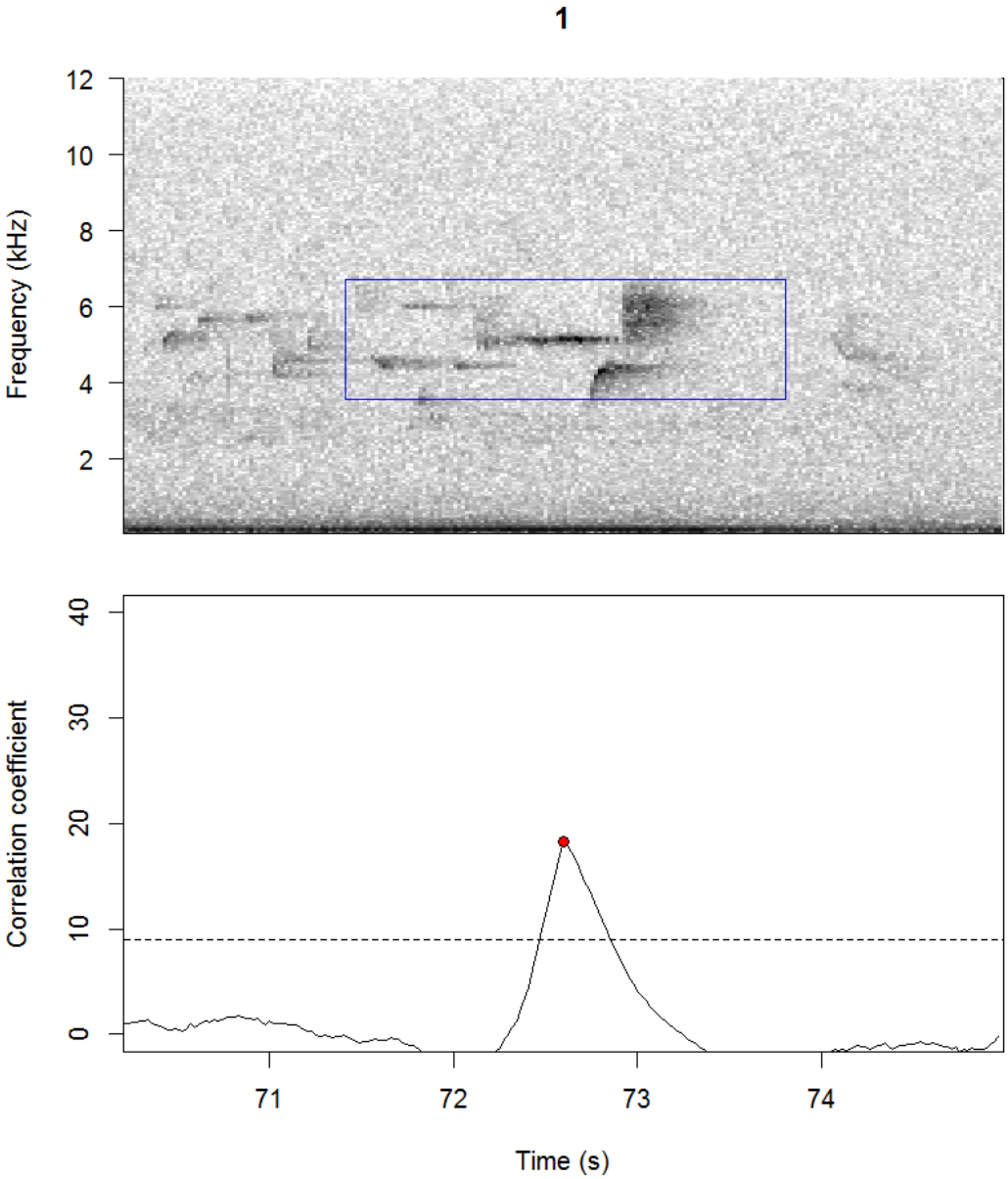
scorelim argument to those values. If using binaryPtMatch the scores typically range between 0 and 40, so use those values instead.

```
CORpks<-showPeaks(
      detection.obj=scc,
      which.one='BTNWd1.0',
      scorelim=c(0,1),
      verify=TRUE,
      player='play')

1. True detection? Enter y or n
1: y
1. TRUE
```




```
BINpks<-showPeaks(
      detection.obj=scores,
      scorelim=c(0,40),
      verify=TRUE,
      player='play')

1. True detection? Enter y or n
```

```
1: y
1. TRUE
```



Running these commands will bring up the graphics above, and the R console will offer the option to mark it as a true detection (press y and ENTER), a false detection (press n and ENTER), or play the clip using the previously specified player (press p and ENTER). If unsure you can enter na or NA and ENTER.

The hit number is noted at the top, and R will sequentially display all hits in the specified time bounds. Press esc to abort the verification process. Note that the boundary box corresponds to the template time limit and the bandpass filter limits.

View the output by viewing the detection list:

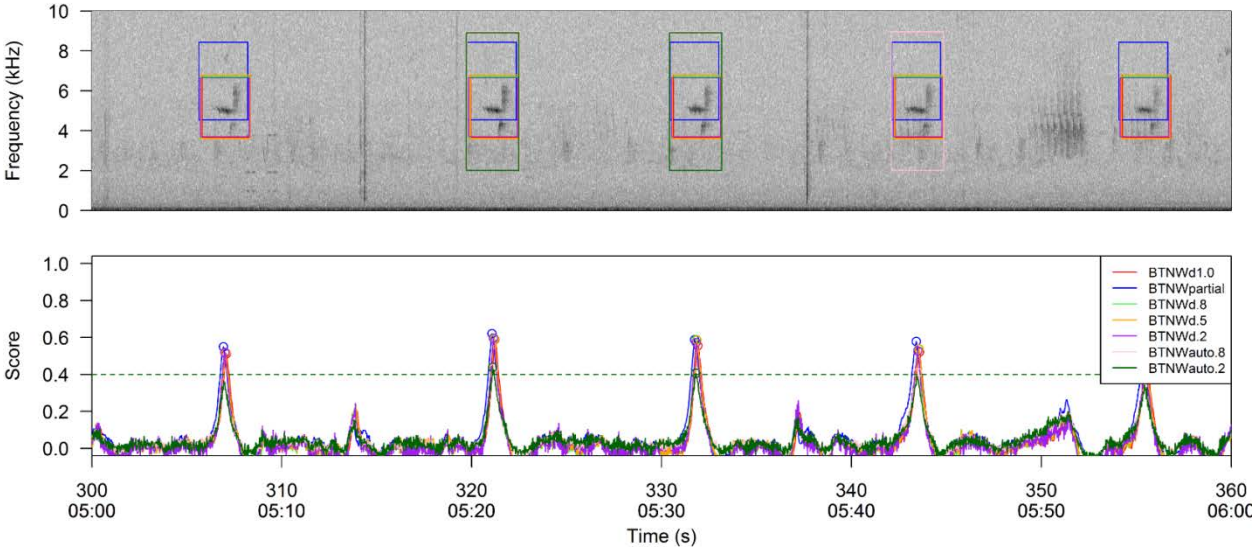
```
CORdetections<-getDetections(CORpks)
BINdetections<-getDetections(BINpks)
```

Verifying correlation results with annotated survey spectrograms

The SpecScorePlot function saves a series of fully customizable annotated spectrograms as PNG files. The output of SpecScorePlot does not need to be assigned to an object. Instead, specify the spectrogram frequency limits, the duration of each spectrogram in seconds, a location to save the graphics files, and a hit marker type:

```
specScorePlot(
      detection.obj=CORpks,
      flim=c(0,10),
      scorelim=c(0,1),
      t.each=60,
      file.name='~/Dropbox/LabDemo/_scc_MABI2_A_062510_',
      hit.marker='points')
```

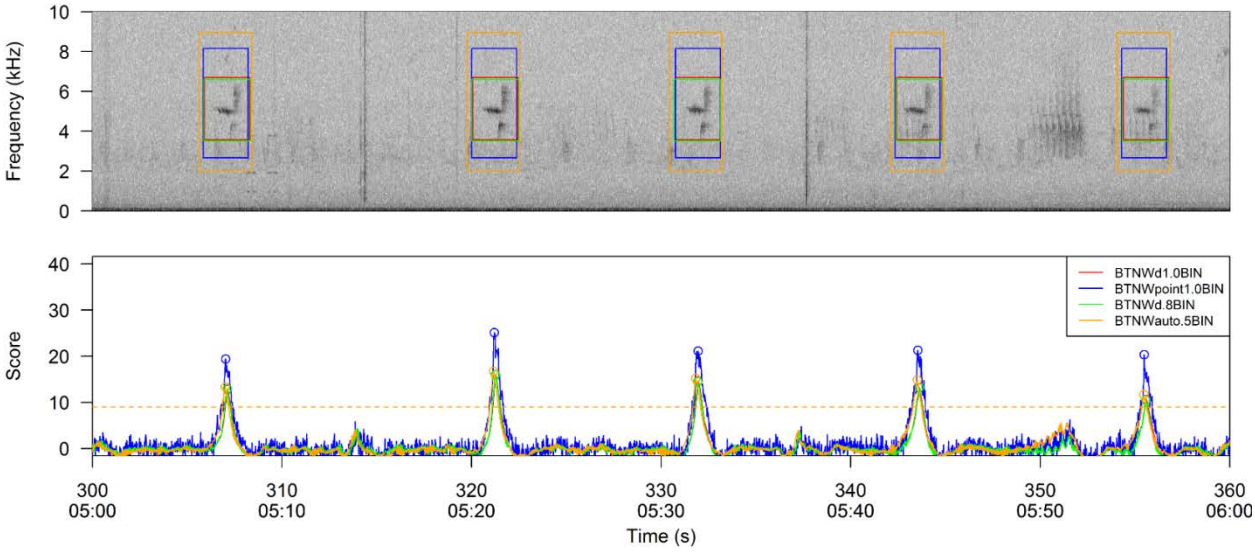
The resulting PNG files will be numbered sequentially, so the first 60 second spectrogram (specified with the t.each argument) will be scc_MABI2_A_062510_001.PNG, the second will be scc_MABI2_A_062510_002.PNG, etc. An example file looks like this:



Verifying binaryPtMatch results with annotated survey spectrograms

Verify the results using the showPeaks, SpecScorePlot, and collapseClips function as described in the sccCor verification section. Be aware when specifying a scoreLim value that sccCor will produce a correlation plot in which values are in the set (0, 1) but with binaryPtMatch the difference between mean on and off values will be plotted, which should range within the set (0, 40).

```
specScorePlot(
      detection.obj=BINpks,
      flim=c(0,10),
      scorelim=c(0,40),
      t.each=60,
      file.name='~/Dropbox/LabDemo/_bin_MABI2_A_062510_',
      hit.marker='points')
```



Storing Results

In a CSV file

To write a csv of the table you wish to store, use getPeaks or getDetections to retrieve all peaks or just detections.

Assign the output to a new object:

```
CORpeaks<-getPeaks(CORpks)
BINpeaks<-getPeaks(BINpks)
CORdetections<-getDetections(CORpks)
BINdetections<-getDetections(BINpks)
```

Save the output file by writing it to a csv:

```
write.csv(BINpeaks, file='E:/users/jkatz3/Desktop/BTNWpeaks.csv')
write.csv(BINdetections, file='E:/users/jkatz3/Desktop/BTNWdetections.csv')
```

In the database

The dbUploadResult function uploads the results either as all peaks or as just detections. Once in the database the results automatically associate with the proper survey (based on the survey name).

```
# Send all pks
dbUploadResult(detection.obj=BINpks,what='peaks', analysis.type='BIN')
# Send hits (from findPeaks) to tblResult; default is what='detections'
dbUploadResult(detection.obj=BINpks,analysis.type='BIN')
```

Archiving Surveys and Hits

Archiving Surveys

The storage volume necessary to archive full survey files is substantial, but it opens the door to future reanalysis as algorithms improve. NETN will store all surveys used during analysis. SongMeter recordings will be archived as WAV files and subsampled Olympus surveys will be archived as MP3 files.

Archiving detections as WAV clips

If full surveys are archived it is not necessary to archive detections separately, but in other cases it is recommended to archive event detections. Archiving event detections has a number of advantages beyond simply providing evidence of a species' presence, including the ability to resolve future taxonomic splits. Although NETN will be archiving full survey files (making archiving detections unnecessary), it may be helpful to store some example files for each species to save having to reconstruct examples from file names and locations of detections within each file.

The function to export the hits in a series of hits-only spectrograms is **collapseClips**. The output will be a single WAV file with all clips of a species within it, which you should assign to an object:

```
hits.btnw <- collapseClips(rec=survey,  start.times= BINdetections$time -
      1.5,  end.times= BINdetections$time + 1.5)
```

The output is a single wave object containing all hits bound together, which you could write to a wave file:

```
writeWave(hits.btnw, 'E:/users/jkatz3/ArchivedHits/Survey1/btnw.wav')
```

If you write the object to a new WAV file for archiving it will be useful to make a "key" to identify when in the original survey each clip occurred. To record this, add the return.times argument to collapseClips:

```
hits.btnw <- collapseClips(rec=survey,  start.times= BINdetections$time -
      1.5,  end.times= BINdetections$time + 1.5,return.times=TRUE)
```

The output will now be converted to a list, in which the first element is the wave object and the second element is a data frame of the start and end time for each clip:

```
> names(hits.btnw)
[1] "wave"  "times"
```

You can write the wav object to a file using an almost identical call, but specifying the item in the list:

```
writeWave(hits.btnw$wave, 'E:/users/jkatz3/ArchivedHits/Survey1/btnw.wav')
```

You can then attach the key to the list of detections from findPeaks:

```
BINdetections <- cbind(BINdetections,key.times=hits.btnw$times)
```

The list of detections could then be saved as a comma-separated values (csv) file and archived with the sound clips.

The sole disadvantage of archiving events is the volume of dedicated storage required. A 1TB drive should be able to archive over 5,000 hours of mono wave files. If the average song is three seconds long, a location has 10 recorders deployed, and 40 species are present at a location, as many as 17,000 song events per species per site may be archived on the 1 TB disk.

The tables below indicate roughly how many hours of survey recordings can be condensed to fit on a 1 TB disk, assuming a single song duration for all species.

Estimated condensed survey hours, 2 second song duration

Songs/hour \ Species/site->	5	10	15	20	25	30
5	41667	20833	13889	10417	8333	6944
10	20833	10417	6944	5208	4167	3472
15	13889	6944	4630	3472	2778	2315
20	10417	5208	3472	2604	2083	1736
25	8333	4167	2778	2083	1667	1389

Estimated condensed survey hours, 3 second song duration

Songs/hour \ Species/site->	5	10	15	20	25	30
5	27778	13889	9259	6944	5556	4630
10	13889	6944	4630	3472	2778	2315
15	9259	4630	3086	2315	1852	1543
20	6944	3472	2315	1736	1389	1157
25	5556	2778	1852	1389	1111	926

Estimated condensed survey hours, 4 second song duration

Songs/hour \ Species/site->	5	10	15	20	25	30
5	20833	10417	6944	5208	4167	3472
10	10417	5208	3472	2604	2083	1736
15	6944	3472	2315	1736	1389	1157
20	5208	2604	1736	1302	1042	868
25	4167	2083	1389	1042	833	694

Extracting, binding, and verifying events listed in data tables

The function bindEvents is designed to read in a data table of start and stop times from a csv file such as the output from Wildlife Acoutics' Song Scope software, or an object downloaded from the database. This function will extract just the events from the survey, which can then be saved individually or they can be saved as a single file of many clips tied together.

Before using the data table in the function the file must be edited so that all times are in decimal seconds, and at a minimum there must be:

1) a column of start times with the heading "tStart"
2) a column of end times with the heading "tEnd"
3) a column identifying the species with a heading "Species"

Optionally there can also be a column identifying the file of the recording with the heading "FileName".

Use bindEvents by assigning its output to an object in R:

```
event.rec <- bindEvents(
      rec='E:/users/jkatz3/Desktop/BTNWtemplates/SARA3_A_062610.wav',
      file='SongScope/ExampleEventList.csv',
      by.species=TRUE,
      parallel=FALSE)
```

The output from bindEvents is a list of WAV files, with an element for each species. Setting by.species=FALSE will result in a list of one WAV file containing all events. As written above, a summary of the species contained can be viewed by checking the names of event.rec:

```
> names(event.rec)
 [1] "AMCR" "AMGO" "AMRO" "BAWW" "BTNW" "CEDW" "COYE" "GCFL" "GRCA" "OVEN"
[11] "REVI" "RWBL" "SCTA" "SOSP" "WAVI" "WIWR" "YWAR"
```

And the WAV recordings themselves can be written to disk as a single file per species using a quick loop. One of the easiest loops to write is the 'for' loop, which will allow each file name to include the species and the survey. The syntax of the loop is: for (i in vector) {do function}:

```
for (i in 1:length(event.rec)){
   writeWave(event.rec[[i]],
   file=paste('E:/users/jkatz3/Desktop/SARA3_A_062610_',names(event.rec)[[i]]
   ,'.wav',sep=""))
   }
```

To store an output key add the argument return.times to the bindEvents call:

```
event.rec <- bindEvents(
      rec='E:/users/jkatz3/Desktop/BTNWtemplates/SARA3_A_062610.wav',
      file='SongScope/ExampleEventList.csv',
      by.species=TRUE,
      parallel=FALSE,
      return.times=TRUE)
```

Adding this argument adds a new element to the output list called times, and moves the wave files to a lower level in the list:

```
> names(event.rec)
[1] "times" "wave"

> names(event.rec$times)
 [1] "AMCR" "AMGO" "AMRO" "BAWW" "BTNW" "CEDW" "COYE" "GCFL" "GRCA" "OVEN"
[11] "REVI" "RWBL" "SCTA" "SOSP" "WAVI" "WIWR" "YWAR"

> names(event.rec$wave)
 [1] "AMCR" "AMGO" "AMRO" "BAWW" "BTNW" "CEDW" "COYE" "GCFL" "GRCA" "OVEN"
[11] "REVI" "RWBL" "SCTA" "SOSP" "WAVI" "WIWR" "YWAR"
```

You can write the wave object to a file using an almost identical loop, but specifying the item in the list:

```
for (i in 1:length(event.rec$wave)){
   writeWave(event.rec$wave[[i]],
   file=paste('E:/users/jkatz3/Desktop/SARA3_A_062610_',names(event.rec$wave)
   [[i]],'.wav',sep=""))
   }
```

You can then save the keys individually using a similar loop:

```
for (i in 1:length(event.rec$times)){
   write.csv(event.rec$times[[i]],
```

```
   file=paste('E:/users/jkatz3/Desktop/SARA3_A_062610_',names(event.rec$times
   )[[i]],'.csv',sep=""))
}
```

Or aggregate them and save a single master key:

```
event.key <- rbind.fill(event.rec$times)
write.csv(event.key, 'E:/users/jkatz3/Desktop/ SARA3_A_062610_key.csv')
```

Batch Analysis

To make batch analysis easier you should plan ahead with your file management when you download field recordings. Use the file management structure outlined at the beginning of this document, in which all recordings are aggregated by recorder within a directory for the date of download.

Imagine all recordings from the SD cards are in a directory named 20100510, which is a date in the format YYYYMMDD. Within this directory are four more folders containing the survey recordings from each recorder. These directories are named after each site: SARA0001, SARA0002, SARA0003, SARA0004.

For batch analysis, use sccDetect, which calls sccCor and findPeaks and then writes out the results as a series of csv files.

The steps the 'for' loop needs to complete are:

1) create a list of recorders
2) loop through the list of recorders, creating a list of surveys for each recorder
3) loop through the list of surveys, reading in one survey at a time
4) call sccDetect to perform sccCor and findPeaks on the survey and save the results
5) export just the clips for verification/long-term storage, if necessary
6) open the next survey and repeat from step 4

For example, to search for these three bird species: Ovenbird (oven), Black-throated Green Warbler (btnw), and Song Sparrow (sosp). Load your templates for these species, using the bandpass filter values and cutoff values stored in the template:

```
templates<-makeTemplates(
    wave.L=list(
      oven='F:/users/jkatz3/templates/oven.wav',
      btnw='F:/users/jkatz3/templates/btnw.wav',
      sosp='F:/users/jkatz3/templates/sosp.wav'
      ),
    frq.lim.L=list(
      oven=c(3,6.9),
      btnw=c(4.1,6.7),
      sosp=c(1.5,7)
      ),
    score.cutoff.L=list(
      oven=0.30,
      btnw=0.41,
      sosp=0.28)
    )
```

The first step of the batch processing is a simple one-command item to list the directories:

```
recorderList <- list.dirs('F:/users/jkatz3/FieldRecordings/20120912')
```

Now we start looping through the recorder list, starting with making a list of survey files:

```
for (i in 1:length(recorderList)){
      surveyList <- list.files(recorderList[i], pattern='\\.wav',
         full.names=TRUE)
      for (j in 1:length(surveyList)){
            survey <- readWave(surveyList[j])
            recorderName <- tail(strsplit(surveyList[j],'/')[[1]],2) #get
               recorder name
            surveyName <- strsplit(recorderName[2],'\\.')[[1]][1]#remove file
               ext from survey name
            fileName <- paste('F:/users/jkatz3/Results/20120912_',
               recorderName[1],'_',surveyName,sep="")
            sccDetect(template.L=templates, survey=survey,
               file.name=fileName)
      }
}
```

Revision History

Version #	Date	Revised by	Changes	Justification
0.10	Sept 2012	Jon Katz	Intial draft.	
0.20	Dec 2012	Jon Katz	Added binary point matching, additional sections.	
0.30	Jan 2013	Geri Tierney, Brian Mitchell	Separated document into SOPfor 1) Audio Detection) and for 2) Template Creation. Editorial and formatting changes.	
0.31	April 2013	Brian Mitchell, Geri Tierney	Provided background information regarding Song Scope and the decision to pursue an R-based analytical approach. Added text for Appendix C, on downloading and installing R. Minor edits for clarity	Response to external review
1.00	May 2013	Jon Katz. Geri Tierney	Accepted changes by BM and GT Replaced figure in Appendix A Added mp3 subsample procedure. Formatting changes. Added survey subsampling procedure for mp3 files.	

Appendix S8.A. Creating a MySQL database

MySQL

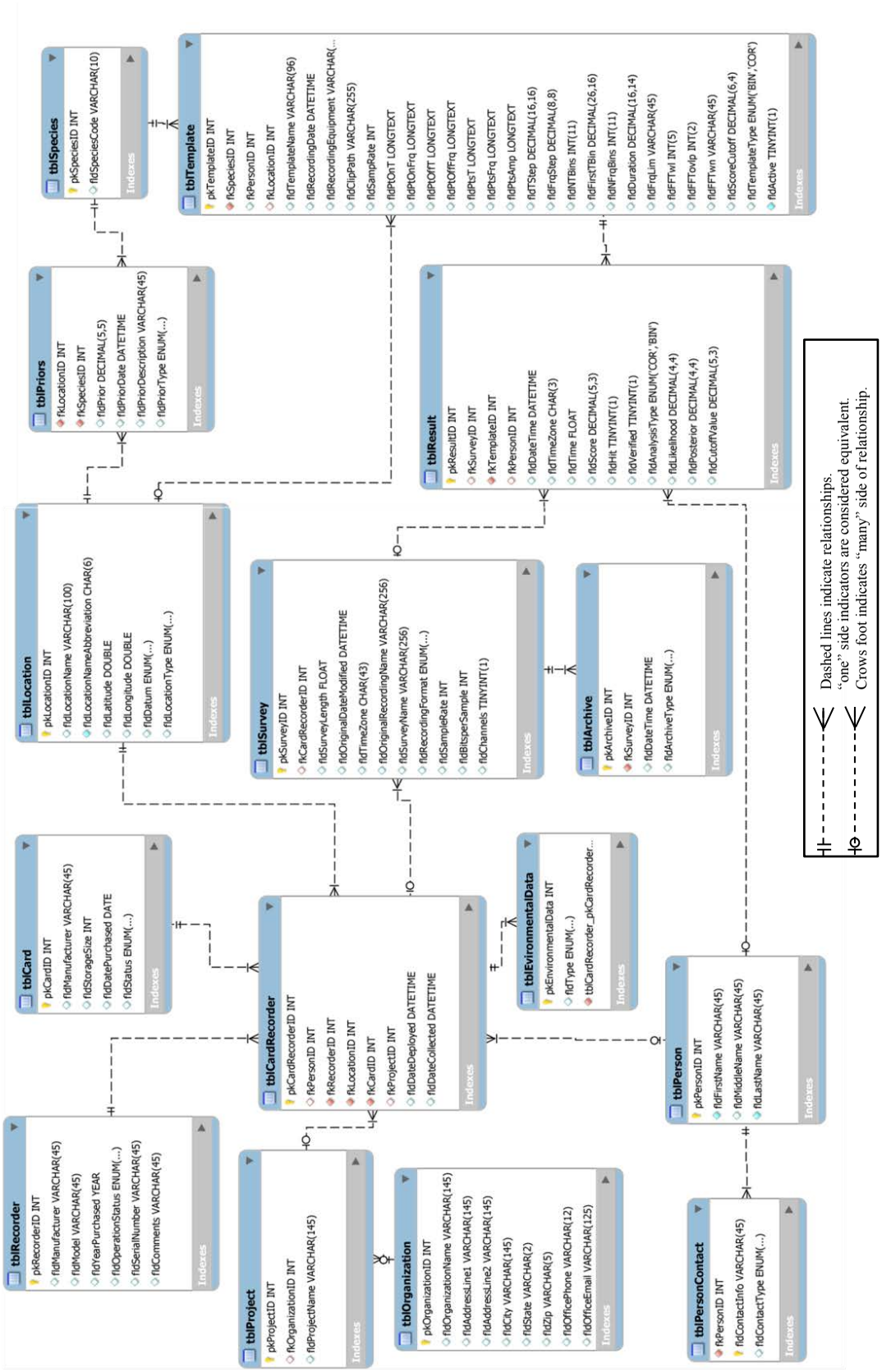
As with most investigations, it is preferable to store information about the project, including the project data, in a relational database. There are several advantages to this, including 1) reduction in errors, 2) ability to have multiple users access the same database, and 3) ability to load results from R directly into the database system.

A relational database consists of a set of tables that relate, or link to, each other. Each table contains information about one thing. For instance, a table called tblPerson stores information about people involved in the acoustic monitoring program. These may include people who deploy and operate recording devices, people who run analyses, etc. A table called tblLocation can store information about the locations in which acoustic recordings were made, including latitude and longitude, the location name, and whether the location is the location of a monitoring site, or whether the location is a place where a template has been recorded.

There are several relational database programs on the market. Acoustic monitoring programs can rapidly acquire massive amounts of data, so space is a key factor in choosing a system. This document will describe the database system called MySQL (http://www.mysql.com/), which can be run from a server (allowing multiple people to use the same database) or from your own computer (assuming you have a very large hard-drive for storing information). If you run MySQL on a server, you likely do not need to install MySQL on your hard drive. However, if you plan to have use a local MySQL database (that is, one that resides on your local disk), you will need to download a copy of MySQL at http://www.apachefriends.org/en/xampp.html along with several other tools. This documentation will assume that the MySQL database is located on a network or the cloud.

Appendix S8.A. Creating a MySQL database (continued)

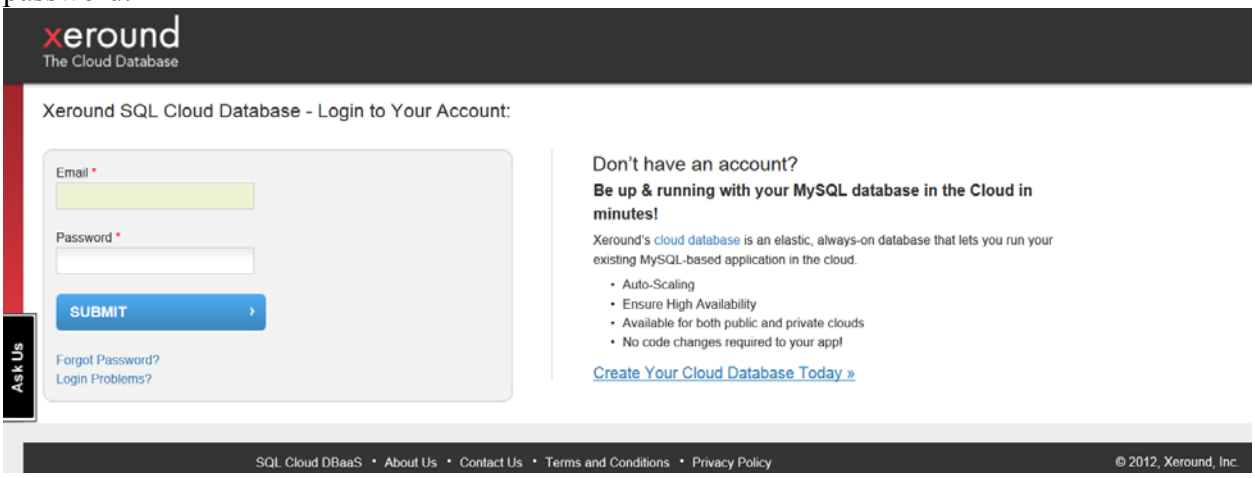
Database Entity Relationship Diagram



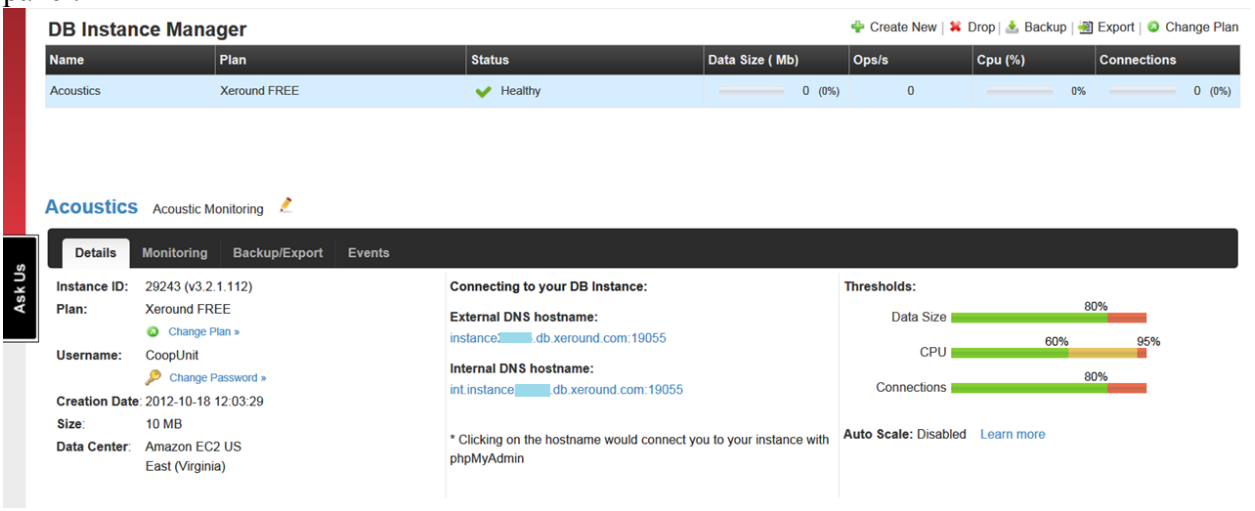
Appendix S8.A. Creating a MySQL database (continued)

Set Up a Cloud Database

Your organization may have a server that allows the creation and storage of a MySQL database. For instance, at the University of Vermont, affiliates can create a database at http://webdb.uvm.edu/. There are many "cloud" database services, and we'll be describing one called Xeround (https://cloud.xeround.com/). The steps are likely to be very similar if you use other formats. You can create an account at Xeround, and then log in with your email and password:

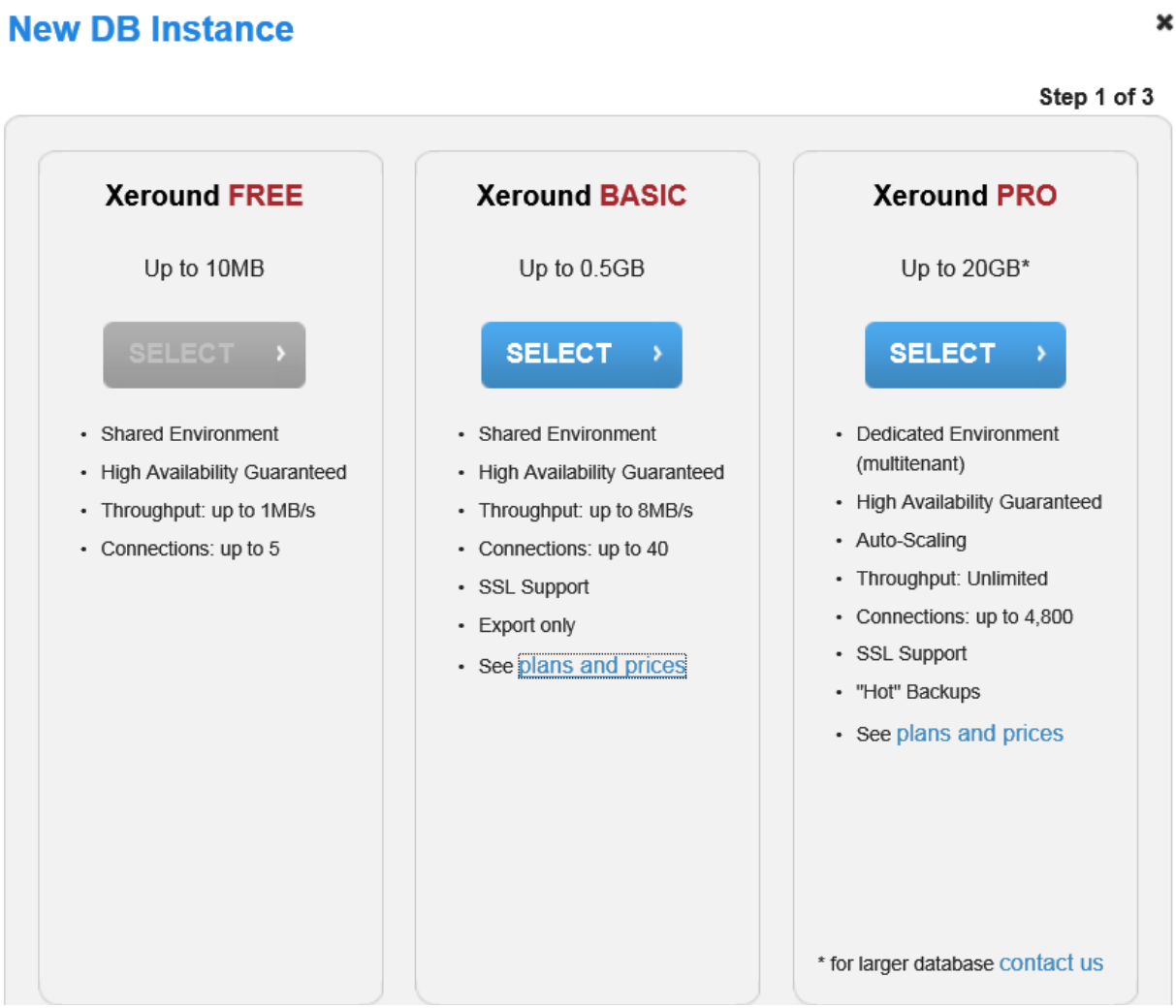

xeround
The Cloud Database
Xeround SQL Cloud Database - Login to Your Account:
Email *
Password *
SUBMIT
Forgot Password?
Login Problems?
Don't have an account?
Be up & running with your MySQL database in the Cloud in minutes!
Xeround's cloud database is an elastic, always-on database that lets you run your existing MySQL-based application in the cloud.
Auto-Scaling
Ensure High Availability
Available for both public and private clouds
No code changes required to your app!
Create Your Cloud Database Today »
Ask Us
SQL Cloud DBaaS • About Us • Contact Us • Terms and Conditions • Privacy Policy
© 2012, Xeround, Inc.

Once you've logged in, you will see a list of your databases in the DB Instance Manager. We have created a database called Acoustics. Information about the database is shown in the lower panel:



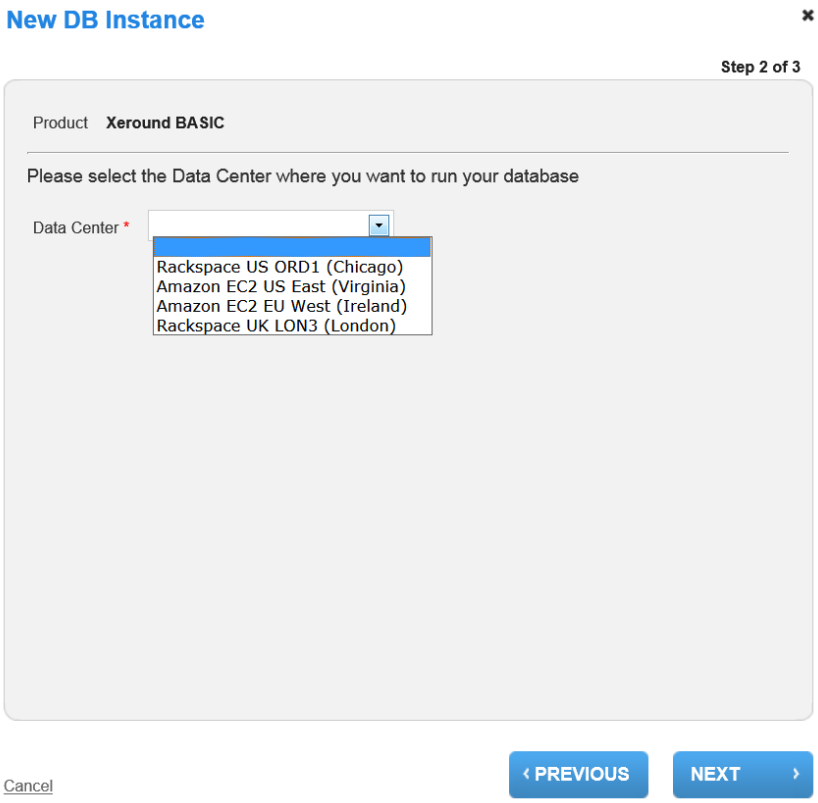
To create the database described above, click on the link called Create New in the top right hand menu, and then select the database size you'd like. We selected the free 10MB version to test this protocol. You may need more space if this becomes your actual, working database. Note that Xeround offers only one free database instance per user.

Appendix S8.A. Creating a MySQL database (continued)



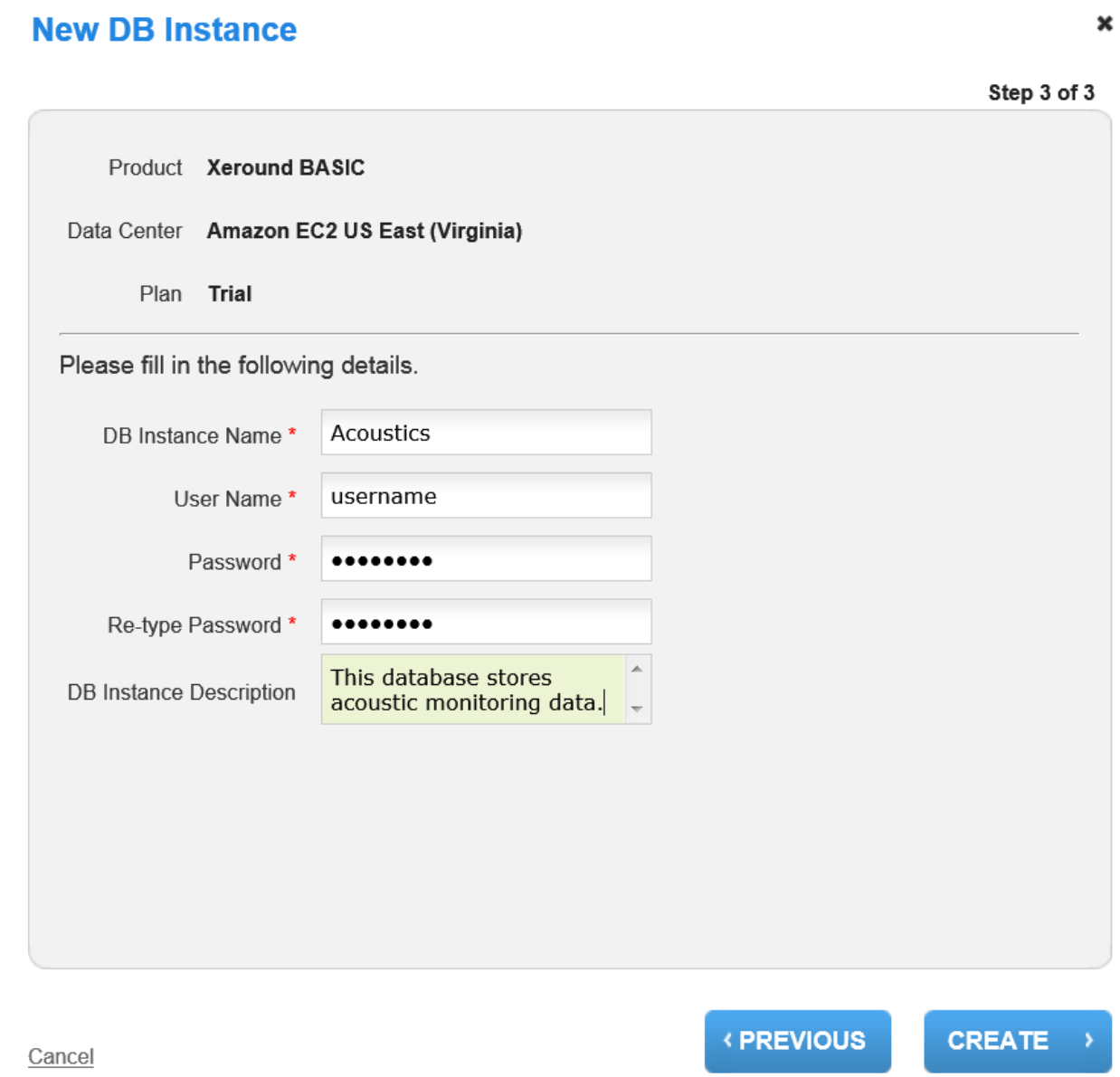
Once you have selected a plan, you will select a Data Center – the location in the cloud that actually will hold your data. Choose the location nearest you, and press Next.

Appendix S8.A. Creating a MySQL database (continued)

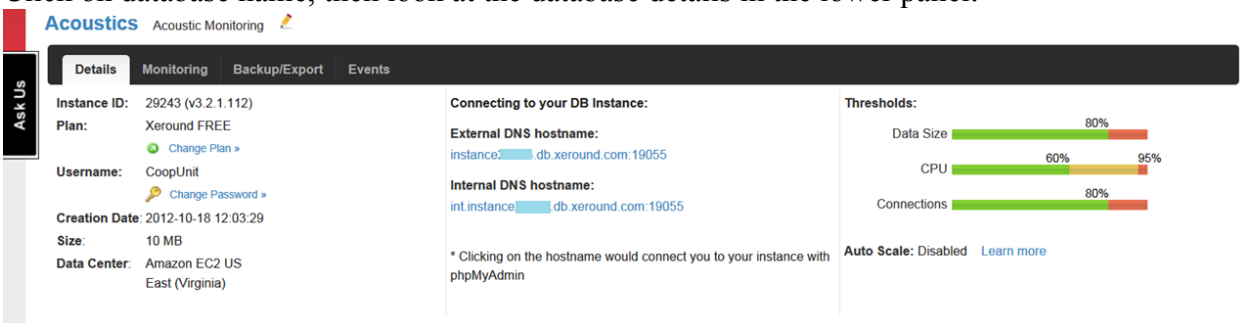


Then fill out the form that follows. Here, you'll enter the name of your database (Acoustics), and identify a username and password. Jot these down because you'll need to use them to connect the database with R.

Appendix S8.A. Creating a MySQL database (continued)



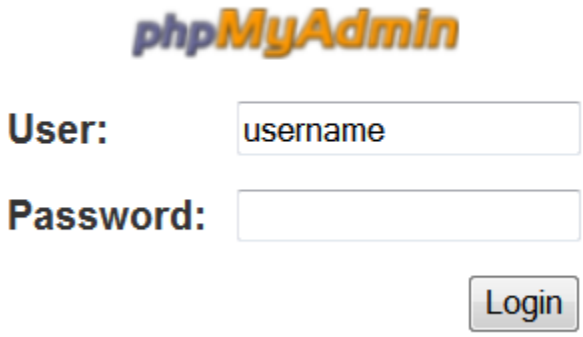
Press Create, and you should see the name of your database listed in the DB Instance Manager. Click on database name, then look at the database details in the lower panel:



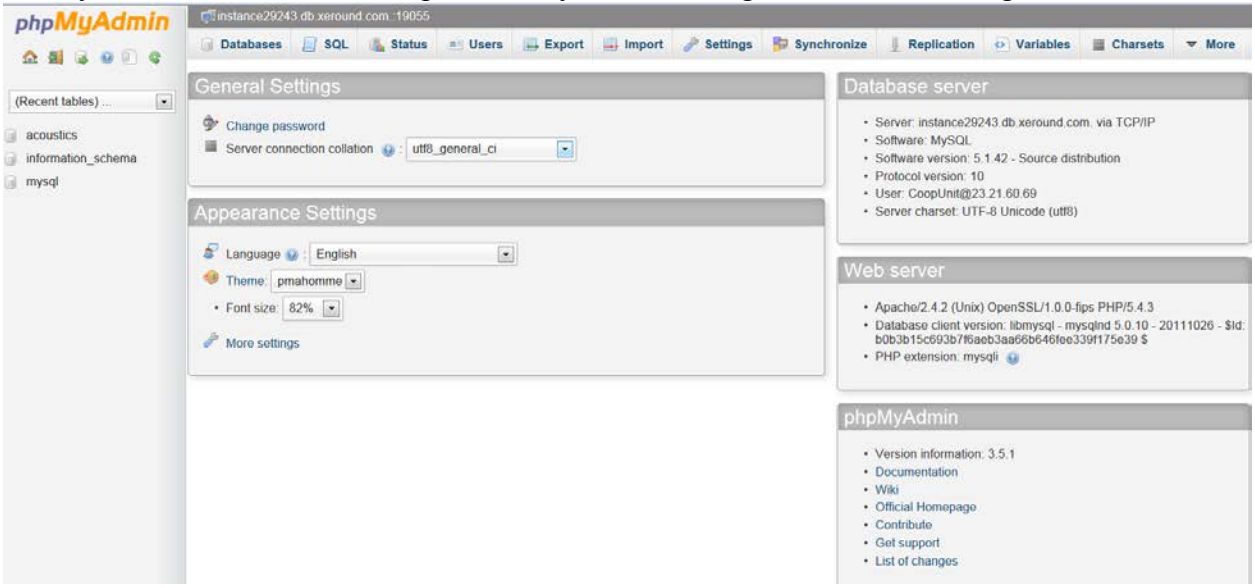
Look for the heading "**External DNS hostname**"; the link below it provides the server name (e.g. instance12345.db.xeround.com) as well as the port number (e.g., 19002). When you click

Appendix S8.A. Creating a MySQL database (continued)

on that link, you will be asked to enter another username and password. This username and password is the username and password for the database you created. If you have multiple databases, each can have their own username and password. You will want to keep tabs on this information as well.

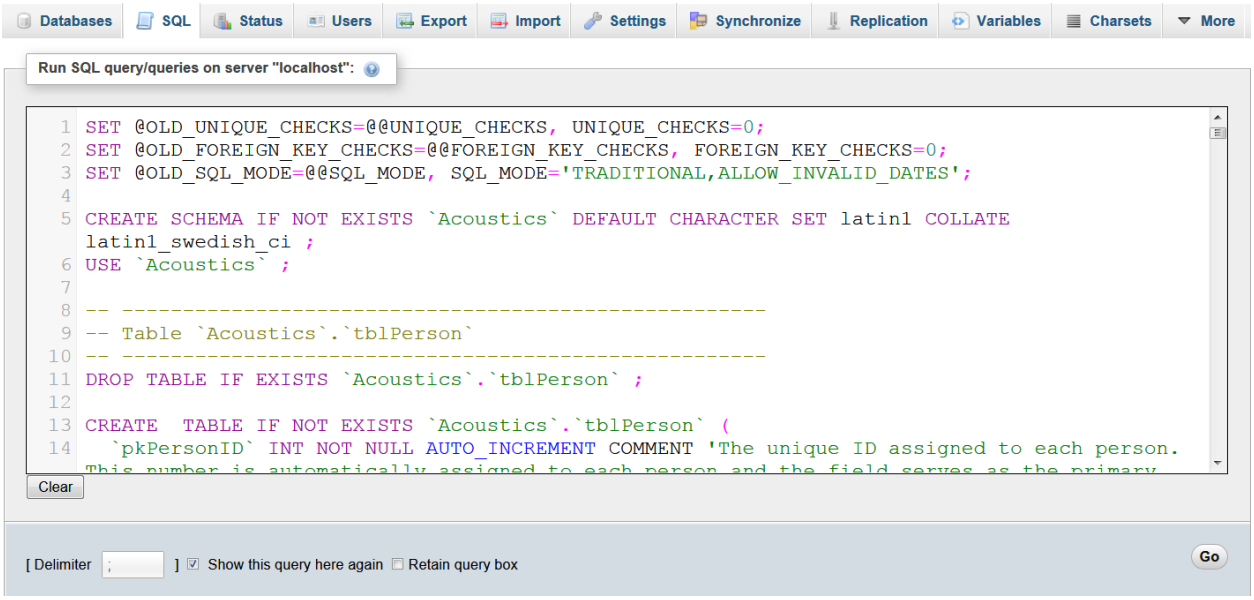


After you select a username and password, you'll be brought to a the following screen:

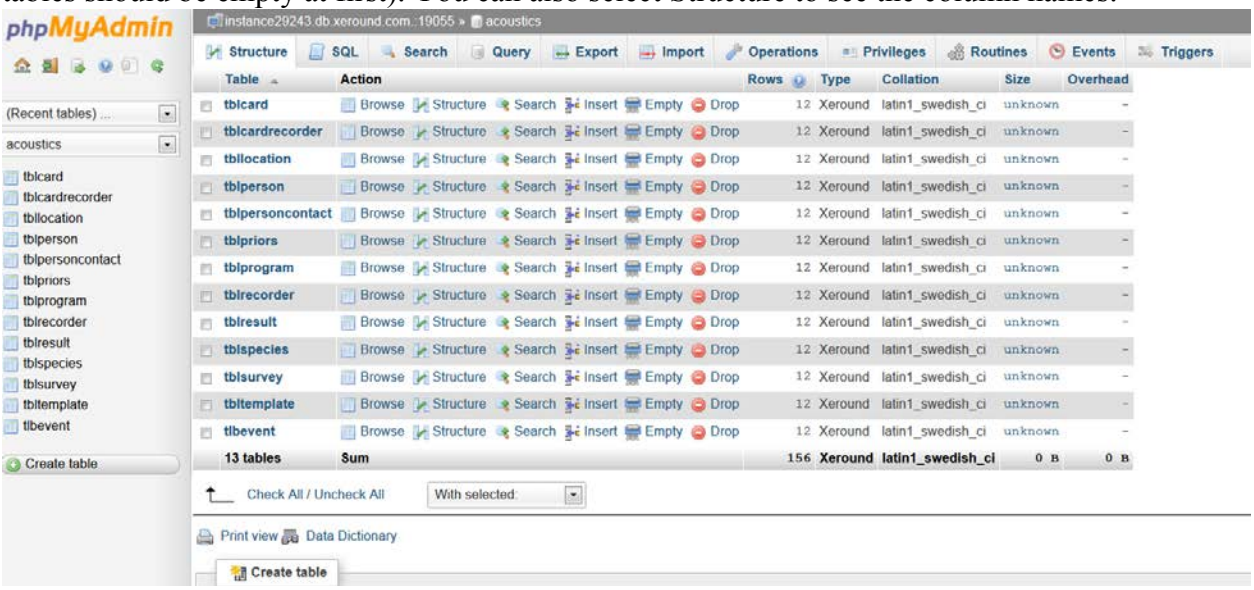


This section is called "phpMyAdmin", and you can think of it as the main page for working with your database. In the left menu, you can see the name of the database you created (acoustics). Notice also the menu at the top of the panel. Poke around to get a feel for what's what….if you get lost just click on the phpMyAdmin logo and you'll be brought back to this home page.
To add the tables previously described to your database, copy the schema from Appendix B. Press the SQL tab and paste it in to the text window, and press the Go button in the lower right corner. This code will create the tables described above, add in table and column descriptions, and assign keys to each table.

Appendix S8.A. Creating a MySQL database (continued)

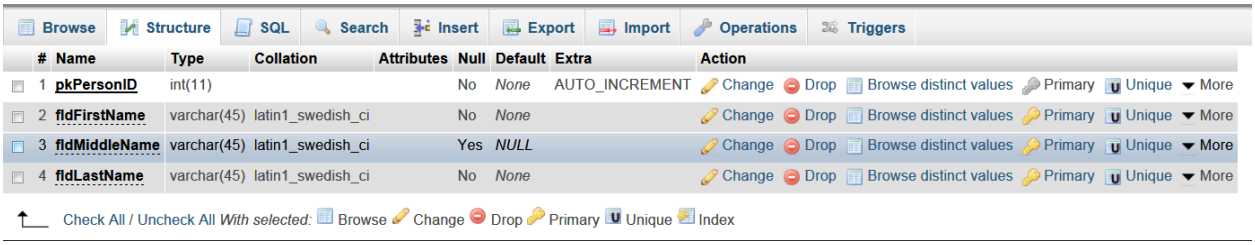


To make sure the code executes successfully, click on the acoustics database in the left menu. You should see all of the tables listed. You can select a table and Browse it to see the data (the tables should be empty at first). You can also select Structure to see the column names:



For example, here is the Structure of tblPerson, showing the four fields that make up this table (pkPersonID, fldFirstName, fldMiddleName, fldLastName). The structure indicates that the pkPersonID is the primary key for this table, and that it is set to AUTO_INCREMENT – this means the database will assign an ID for any new entry.

Appendix S8.A. Creating a MySQL database (continued)

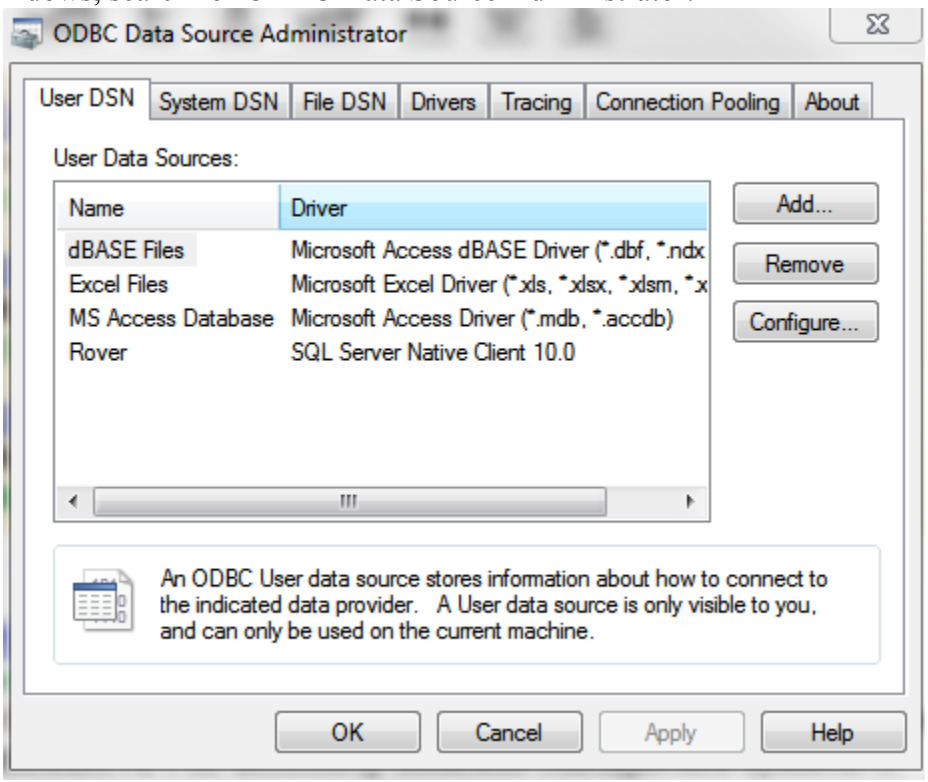

Browse
Structure
SQL
Search
Insert
Export
Import
Operations
Triggers
Name Type Collation Attributes Null Default Extra Action
1 pkPersonID int(11) No None AUTO_INCREMENT Change Drop Browse distinct values Primary Unique More
2 fldFirstName varchar(45) latin1_swedish_ci No None Change Drop Browse distinct values Primary Unique More
3 fldMiddleName varchar(45) latin1_swedish_ci Yes NULL Change Drop Browse distinct values Primary Unique More
4 fldLastName varchar(45) latin1_swedish_ci No None Change Drop Browse distinct values Primary Unique More
Check All / Uncheck All With selected: Browse Change Drop Primary Unique Index

If you'd like to insert some records to your database, you can click on the Insert tab and try it out. However, we will hardly be using this interface at all from this point on. You'll use Microsoft Access as a "front end" to enter data into the database, and you'll also use R. In order to allow these program to work with your new database, you'll need to create an ODBC connection on your computer, and we'll do that next.

Setting up an ODBC Connection

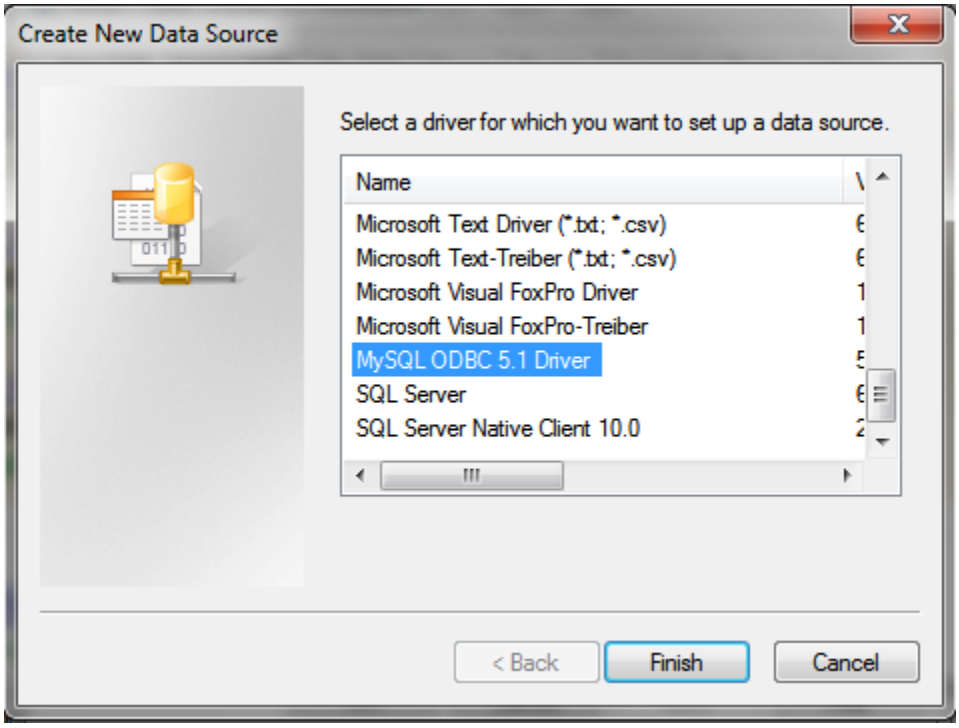
To let your computer interface with your new MySQL database, you'll need to set up an ODBC connection (Open Database Connectivity). Here's how:

1. Windows Operating Systems.
    a. In Windows, search for ODBC Data Source Administrator:



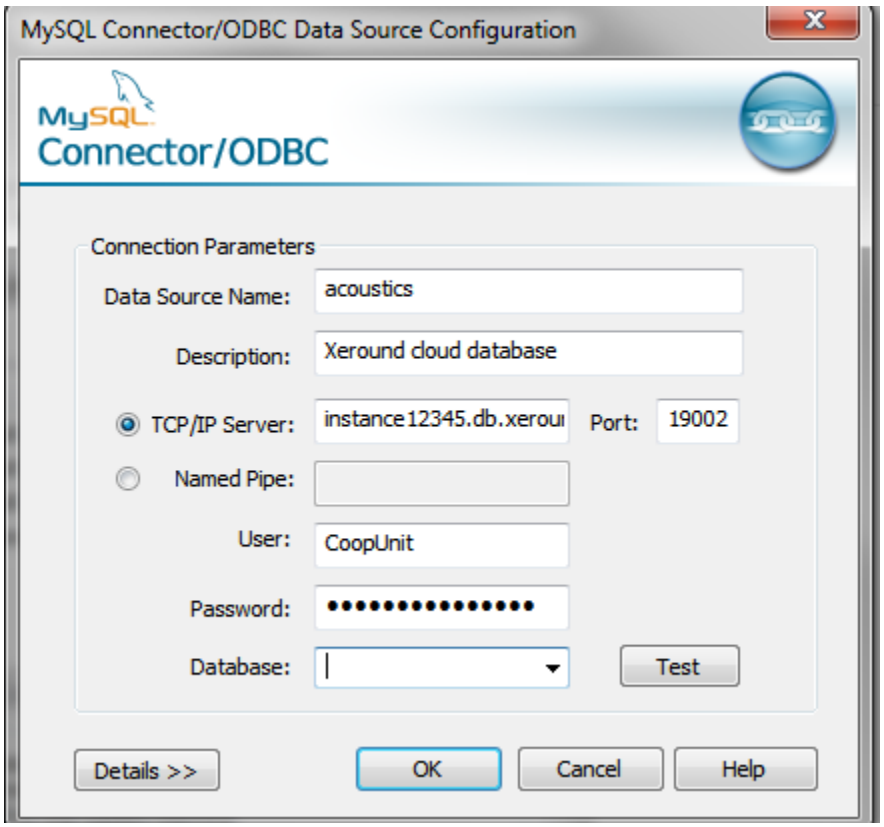
    b. Click on the User DSN tab, and click Add. This will store the connection information associated with your Windows user log in. Then choose MySQL ODBC 5.1 Driver (or higher). Then click Finish.

Appendix S8.A. Creating a MySQL database (continued)

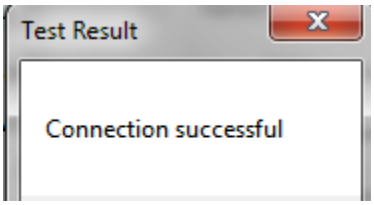


c. Fill in the dialogue box that appears. Here, you'll enter what name you want to give this connection (we called it acoustics, the default for the dbUpload/Download functions), and a short description. You will also enter the server name and port (see "Set up a cloud database", above). The User name and password are the strings associated with the database itself. When you enter the server and port, and fill in the correct identity, the name of your database should appear in the database box.

Appendix S8.A. Creating a MySQL database (continued)



d. Clicking on the test button will let you know for sure whether you were able to successfully connect to the cloud database. If you make it this far, you have successfully created an ODBC connection on your Windows machine. We'll use this connection to link R to the database, importing results into the database. This same connection will be used to link Access to the database if you choose to use the Access front end, which provides some data entry forms for tables such as tblPerson, tblCard, tblLocation, etc.



Appendix S8.B. Database Schema

```
SET @OLD_UNIQUE_CHECKS=@@UNIQUE_CHECKS, UNIQUE_CHECKS=0;
SET @OLD_FOREIGN_KEY_CHECKS=@@FOREIGN_KEY_CHECKS, FOREIGN_KEY_CHECKS=0;
SET @OLD_SQL_MODE=@@SQL_MODE, SQL_MODE='TRADITIONAL,ALLOW_INVALID_DATES';


-- -----------------------------------------------------
-- Table `acoustics`.`tblPerson`
-- -----------------------------------------------------
DROP TABLE IF EXISTS `acoustics`.`tblPerson` ;

CREATE  TABLE IF NOT EXISTS `acoustics`.`tblPerson` (
  `pkPersonID` INT NOT NULL AUTO_INCREMENT COMMENT 'The unique ID assigned to
each person.  This number is automatically assigned to each person and the
field serves as the primary key for the table.' ,
  `fldFirstName` VARCHAR(45) NOT NULL COMMENT 'The individuals first name.' ,
  `fldMiddleName` VARCHAR(45) NULL COMMENT 'The individuals middle name.' ,
  `fldLastName` VARCHAR(45) NOT NULL COMMENT 'The individuals last name.' ,
  PRIMARY KEY (`pkPersonID`) )
ENGINE = InnoDB
COMMENT = 'Names of people in the monitoring program.';


-- -----------------------------------------------------
-- Table `acoustics`.`tblLocation`
-- -----------------------------------------------------
DROP TABLE IF EXISTS `acoustics`.`tblLocation` ;

CREATE  TABLE IF NOT EXISTS `acoustics`.`tblLocation` (
  `pkLocationID` INT NOT NULL AUTO_INCREMENT COMMENT 'These numbers are
automatically assigned, and serve as the the primary key for this table.' ,
  `fldLocationName` VARCHAR(100) NULL COMMENT 'The name or description of the
location. For example, Saratoga National Historic Park.' ,
  `fldLocationNameAbbreviation` CHAR(6) NOT NULL COMMENT 'The 6 digit
abbreviation for the location name. E.g., SARA01.  Required.' ,
  `fldLatitude` DOUBLE NULL COMMENT 'The latitude of the location.  Google
Maps or Google Earth can be used to get latitude and longitude.  ' ,
  `fldLongitude` DOUBLE NULL COMMENT 'The longitude of the location.  Google
Maps or Google Earth can be used to get latitude and longitude.  ' ,
  `fldDatum` ENUM('WGS84','NAD27','NAD83','GRS80') NULL DEFAULT 'WGS84'
COMMENT 'The datum of the latitude and longitude.  Default is WGS84.  ' ,
  `fldLocationType` ENUM('Site','Template') NULL COMMENT 'The type of the
location:  \\\'Site\\\' for a monitoring site, \\\'Template\\\' for the
location of a recording made expressly for creating a template.' ,
  PRIMARY KEY (`pkLocationID`) )
ENGINE = InnoDB
COMMENT = 'This table stores information about about all locations in t' /*
comment truncated */;


-- -----------------------------------------------------
-- Table `acoustics`.`tblSpecies`
-- -----------------------------------------------------
```

Appendix S8.B. Database Schema (continued)

```
DROP TABLE IF EXISTS `acoustics`.`tblSpecies` ;
CREATE  TABLE IF NOT EXISTS `acoustics`.`tblSpecies` (
  `pkSpeciesID` INT NOT NULL AUTO_INCREMENT COMMENT 'The unique number
assigned to a specific species. This number is automatically assigned, and
serves as the primary key for this table.' ,
  `fldSpeciesCode` VARCHAR(10) NULL COMMENT 'The four, six, eight, or ten
letter code which identifies a particular species. ' ,
  PRIMARY KEY (`pkSpeciesID`) )
ENGINE = InnoDB
COMMENT = 'Store species info.  Use BBL codes or other 4, 6, or 8 chara' /*
comment truncated */;


-- -----------------------------------------------------
-- Table `acoustics`.`tblTemplate`
-- -----------------------------------------------------
DROP TABLE IF EXISTS `acoustics`.`tblTemplate` ;

CREATE  TABLE IF NOT EXISTS `acoustics`.`tblTemplate` (
  `pkTemplateID` INT NOT NULL AUTO_INCREMENT ,
  `fkSpeciesID` INT NOT NULL ,
  `fkPersonID` INT NULL ,
  `fkLocationID` INT NULL ,
  `fldTemplateName` VARCHAR(96) NULL COMMENT 'Name should refer to the
species code and allow for multiple templates per species' ,
  `fldRecordingDate` INT NULL COMMENT 'Date template sound clip was recorded'
,
  `fldRecordingEquipment` VARCHAR(100) NULL COMMENT 'Make & model of recorder
and microphone.' ,
  `fldClipPath` VARCHAR(255) NULL COMMENT 'Full file path to clip.' ,
  `fldSampRate` INT NULL COMMENT 'Sample rate of clip.' ,
  `fldPtOn` LONGTEXT NULL COMMENT '\\\"On\\\" points (binary templates
only).' ,
  `fldPtOff` LONGTEXT NULL COMMENT '\\\"Off\\\" points (binaryPtMatch only).'
,
  `fldPts` LONGTEXT NULL COMMENT 'All points (correlation templates only).' ,
  `fldTStep` DECIMAL(16,16) NULL COMMENT 'Size of time steps.' ,
  `fldFrqStep` DECIMAL(8,8) NULL COMMENT 'Size of frequency steps.' ,
  `fldNTBins` INT(11) NULL COMMENT 'Number of time bins.' ,
  `fldFirstTBin` DECIMAL(26,16) NULL COMMENT 'Time of first time bin in
clip.' ,
  `fldNFrqBins` INT(11) NULL COMMENT 'Number of frequency bins.' ,
  `fldDuration` DECIMAL(16,14) NULL COMMENT 'Duration of template (seconds).'
,
  `fldFrqLim` VARCHAR(45) NULL COMMENT 'Frequency limits of template.' ,
  `fldFFTwl` INT(5) NULL COMMENT 'FFT window length.  Powers of 2: 64, 128,
256, 512, 1024, 2048.' ,
  `fldFFTovlp` INT(2) NULL COMMENT 'FFT overlap, in %.' ,
  `fldFFTwn` VARCHAR(45) NULL COMMENT 'Window function name.' ,
  `fldScoreCutoff` DECIMAL(6,4) NULL COMMENT 'Score cutoff for template.' ,
  `fldTemplateType` ENUM('BIN','COR') NULL COMMENT 'Type of template: binary
or correlation.' ,
  `fldActive` TINYINT(1) NOT NULL COMMENT '1=active, 0=inactive.' ,
  PRIMARY KEY (`pkTemplateID`) ,
  CONSTRAINT `fk_tblTemplate_tblSpecies1`
```

Appendix S8.B. Database Schema (continued)

```
    FOREIGN KEY (`fkSpeciesID` )
    REFERENCES `acoustics`.`tblSpecies` (`pkSpeciesID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION,
  CONSTRAINT `fk_tblTemplate_tblLocation1`
    FOREIGN KEY (`fkLocationID` )
    REFERENCES `acoustics`.`tblLocation` (`pkLocationID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION)
ENGINE = InnoDB
COMMENT = 'Store templates and template metadata.';

CREATE INDEX `fk_tblTemplate_tblSpecies1_idx` ON `acoustics`.`tblTemplate`
(`fkSpeciesID` ASC) ;

CREATE INDEX `fk_tblTemplate_tblLocation1_idx` ON `acoustics`.`tblTemplate`
(`fkLocationID` ASC) ;

CREATE UNIQUE INDEX `fldTemplateName_UNIQUE` ON `acoustics`.`tblTemplate`
(`fldTemplateName` ASC) ;

-- -----------------------------------------------------
-- Table `acoustics`.`tblRecorder`
-- -----------------------------------------------------
DROP TABLE IF EXISTS `acoustics`.`tblRecorder` ;

CREATE  TABLE IF NOT EXISTS `acoustics`.`tblRecorder` (
  `pkRecorderID` INT NOT NULL AUTO_INCREMENT COMMENT 'This number is assigned
automatically, and serves as the primary key for the table.' ,
  `fldManufacturer` VARCHAR(45) NULL COMMENT 'The manufacturer of the
recording unit, e.g. Wildlife Acoustics.' ,
  `fldModel` VARCHAR(45) NULL COMMENT 'The model of the recording unit, e.g.
SM2. ' ,
  `fldYearPurchased` YEAR NULL COMMENT 'The year the unit was purchased.' ,
  `fldOperationStatus` ENUM('In Service','Needs Repair','Recycled') NULL
COMMENT 'The status of the unit:  In Service, Needs Repair, or Recycled (no
longer an asset of the program)  ' ,
  `fldSerialNumber` VARCHAR(45) NULL COMMENT 'The manufacturer\\\'s serial
number of the unit.' ,
  `fldComments` VARCHAR(45) NULL COMMENT 'Comments about the unit.  ' ,
  PRIMARY KEY (`pkRecorderID`) )
ENGINE = InnoDB
COMMENT = 'This table stores information about recording units.';

CREATE UNIQUE INDEX `pkRecorderID_UNIQUE` ON `acoustics`.`tblRecorder`
(`pkRecorderID` ASC) ;

-- -----------------------------------------------------
-- Table `acoustics`.`tblCard`
-- -----------------------------------------------------
DROP TABLE IF EXISTS `acoustics`.`tblCard` ;

CREATE  TABLE IF NOT EXISTS `acoustics`.`tblCard` (
  `pkCardID` INT NOT NULL AUTO_INCREMENT COMMENT 'This field assigns a unique
number to each SD card used in the monitoring program.  This number is
```

Appendix S8.B. Database Schema (continued)

```
automatically assigned, and the field serves as the primary key for this
table.' ,
  `fldManufacturer` VARCHAR(45) NULL COMMENT 'The manufacturer of the card,
e.g. Sandisk.' ,
  `fldStorageSize` INT NULL COMMENT 'This is the size of the card, in GB.
For example, 256 is a 256 GB card.' ,
  `fldDatePurchased` DATE NULL COMMENT 'The date the card was purchased.' ,
  `fldStatus` ENUM('Active','Failed') NULL COMMENT 'The status of the card:
Active or Failed.' ,
  PRIMARY KEY (`pkCardID`) )
ENGINE = InnoDB
COMMENT = 'This table stores information about memory cards.';

-- -----------------------------------------------------
-- Table `acoustics`.`tblOrganization`
-- -----------------------------------------------------
DROP TABLE IF EXISTS `acoustics`.`tblOrganization` ;

CREATE  TABLE IF NOT EXISTS `acoustics`.`tblOrganization` (
  `pkOrganizationID` INT NOT NULL AUTO_INCREMENT ,
  `fldOrganizationName` VARCHAR(145) NULL ,
  `fldAddressLine1` VARCHAR(145) NULL ,
  `fldAddressLine2` VARCHAR(145) NULL ,
  `fldCity` VARCHAR(145) NULL ,
  `fldState` VARCHAR(2) NULL ,
  `fldZip` VARCHAR(5) NULL ,
  `fldOfficePhone` VARCHAR(12) NULL ,
  `fldOfficeEmail` VARCHAR(125) NULL ,
  PRIMARY KEY (`pkOrganizationID`) )
ENGINE = InnoDB
COMMENT = 'Store the organization name and contact info here.';

-- -----------------------------------------------------
-- Table `acoustics`.`tbProject`
-- -----------------------------------------------------
DROP TABLE IF EXISTS `acoustics`.`tbProject` ;

CREATE  TABLE IF NOT EXISTS `acoustics`.`tbProject` (
  `pkProjectID` INT NOT NULL AUTO_INCREMENT ,
  `fkOrganizationID` INT NULL ,
  `fldProjectName` VARCHAR(145) NULL ,
  PRIMARY KEY (`pkProjectID`) ,
  CONSTRAINT `fk_tbProject_tblOrganization1`
    FOREIGN KEY (`fkOrganizationID` )
    REFERENCES `acoustics`.`tblOrganization` (`pkOrganizationID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION)
ENGINE = InnoDB
COMMENT = 'Store the names of multiple projects per organization here.';

CREATE UNIQUE INDEX `pkProgramID_UNIQUE` ON `acoustics`.`tbProject`
(`pkProjectID` ASC) ;

CREATE INDEX `fk_tbProject_tblOrganization1_idx` ON `acoustics`.`tbProject`
(`fkOrganizationID` ASC) ;
```

Appendix S8.B. Database Schema (continued)

```
-- -----------------------------------------------------
-- Table `acoustics`.`tblCardRecorder`
-- -----------------------------------------------------
DROP TABLE IF EXISTS `acoustics`.`tblCardRecorder` ;

CREATE  TABLE IF NOT EXISTS `acoustics`.`tblCardRecorder` (
  `pkCardRecorderID` INT NOT NULL AUTO_INCREMENT ,
  `fkPersonID` INT NULL COMMENT 'The person who deploys the recording unit.'
,
  `fkRecorderID` INT NOT NULL COMMENT 'This foreign key references the unit
number (pkUnitID) stored in tblRecordingUnits.' ,
  `fkLocationID` INT NOT NULL COMMENT 'The location in which the unit was
deployed.' ,
  `fkCardID` INT NOT NULL COMMENT 'This is a foreign key referencing the
pkCardID in tblCard.' ,
  `fkProjectID` INT NULL ,
  `fldDateDeployed` DATETIME NULL COMMENT 'The date that the card was
installed in the recording unit.' ,
  `fldDateCollected` DATETIME NULL COMMENT 'The date that the card was
retrieved from the recording unit.' ,
  PRIMARY KEY (`pkCardRecorderID`) ,
  CONSTRAINT `fk_tblRecordings_tblPerson`
    FOREIGN KEY (`fkPersonID` )
    REFERENCES `acoustics`.`tblPerson` (`pkPersonID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION,
  CONSTRAINT `fk_tblRecordings_tblRecordingUnit1`
    FOREIGN KEY (`fkRecorderID` )
    REFERENCES `acoustics`.`tblRecorder` (`pkRecorderID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION,
  CONSTRAINT `fk_tblRecordings_tblLocation1`
    FOREIGN KEY (`fkLocationID` )
    REFERENCES `acoustics`.`tblLocation` (`pkLocationID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION,
  CONSTRAINT `fk_tblFieldRecordings_tblCard1`
    FOREIGN KEY (`fkCardID` )
    REFERENCES `acoustics`.`tblCard` (`pkCardID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION,
  CONSTRAINT `fk_tblCardRecorder_tblProgram1`
    FOREIGN KEY (`fkProjectID` )
    REFERENCES `acoustics`.`tbProject` (`pkProjectID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION)
ENGINE = InnoDB
COMMENT = 'Track which surveys are recorded by which recorders via whic' /*
comment truncated */;

CREATE INDEX `fk_tblRecordings_tblPerson_idx` ON
`acoustics`.`tblCardRecorder` (`fkPersonID` ASC) ;

CREATE INDEX `fk_tblRecordings_tblRecordingUnit1_idx` ON
`acoustics`.`tblCardRecorder` (`fkRecorderID` ASC) ;
```

Appendix S8.B. Database Schema (continued)

```
CREATE INDEX `fk_tblRecordings_tblLocation1_idx` ON
`acoustics`.`tblCardRecorder` (`fkLocationID` ASC) ;

CREATE INDEX `fk_tblFieldRecordings_tblCard1_idx` ON
`acoustics`.`tblCardRecorder` (`fkCardID` ASC) ;

CREATE UNIQUE INDEX `pkCardRecorder_UNIQUE` ON `acoustics`.`tblCardRecorder`
(`pkCardRecorderID` ASC) ;

CREATE INDEX `fk_tblCardRecorder_tblProgram1_idx` ON
`acoustics`.`tblCardRecorder` (`fkProjectID` ASC) ;

-- -----------------------------------------------------
-- Table `acoustics`.`tblSurvey`
-- -----------------------------------------------------
DROP TABLE IF EXISTS `acoustics`.`tblSurvey` ;

CREATE  TABLE IF NOT EXISTS `acoustics`.`tblSurvey` (
  `pkSurveyID` INT NOT NULL AUTO_INCREMENT ,
  `fkCardRecorderID` INT NULL ,
  `fldSurveyLength` FLOAT NULL COMMENT 'Survey recording duration, in
seconds.' ,
  `fldOriginalDateModified` DATETIME NULL COMMENT 'Date, time, and time zone
of when the original file was created, closed, and saved.  This is the end
time of the survey.' ,
  `fldTimeZone` CHAR(43) NULL ,
  `fldOriginalRecordingName` VARCHAR(256) NULL COMMENT 'If survey file name
changed during format conversion or to match name standard record original
name here.' ,
  `fldSurveyName` VARCHAR(256) NULL COMMENT 'Current survey file name.' ,
  `fldRecordingFormat` ENUM('WAV','MP3','WAC') NULL COMMENT 'Format of
original survey recording: \\\'WAV\\\', \\\'WAC\\\', or \\\'MP3\\\'.' ,
  `fldSampleRate` INT NULL COMMENT 'Sample rate of survey recording.' ,
  `fldBitsperSample` INT NULL COMMENT 'Bits per sample (WAV) or bit rate
(MP3).' ,
  `fldChannels` ENUM('stereo','mono') NULL COMMENT 'Stereo or Mono.' ,
  PRIMARY KEY (`pkSurveyID`) ,
  CONSTRAINT `fk_tblSurvey_tblCardRecorder1`
    FOREIGN KEY (`fkCardRecorderID` )
    REFERENCES `acoustics`.`tblCardRecorder` (`pkCardRecorderID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION)
ENGINE = InnoDB
COMMENT = 'This table stores attributes of the survey recording.';

CREATE UNIQUE INDEX `pkSurveyID_UNIQUE` ON `acoustics`.`tblSurvey`
(`pkSurveyID` ASC) ;

CREATE INDEX `fk_tblSurvey_tblCardRecorder1_idx` ON `acoustics`.`tblSurvey`
(`fkCardRecorderID` ASC) ;


-- -----------------------------------------------------
-- Table `acoustics`.`tblArchive`
```

Appendix S8.B. Database Schema (continued)

```
-- -----------------------------------------------------
DROP TABLE IF EXISTS `acoustics`.`tblArchive` ;

CREATE  TABLE IF NOT EXISTS `acoustics`.`tblArchive` (
  `pkArchiveID` INT NOT NULL AUTO_INCREMENT ,
  `fkSurveyID` INT NOT NULL ,
  `fldDateTime` DATETIME NULL ,
  `fldArchiveType` ENUM('Original','Hits') NULL ,
  PRIMARY KEY (`pkArchiveID`) ,
  CONSTRAINT `fk_tlbEvents_tblSurvey1`
    FOREIGN KEY (`fkSurveyID` )
    REFERENCES `acoustics`.`tblSurvey` (`pkSurveyID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION)
ENGINE = InnoDB
COMMENT = 'For archiving sound clips extracted from surveys.';

CREATE INDEX `fk_tlbEvents_tblSurvey1_idx` ON `acoustics`.`tblArchive`
(`fkSurveyID` ASC) ;

-- -----------------------------------------------------
-- Table `acoustics`.`tblPriors`
-- -----------------------------------------------------
DROP TABLE IF EXISTS `acoustics`.`tblPriors` ;

CREATE  TABLE IF NOT EXISTS `acoustics`.`tblPriors` (
  `fkLocationID` INT NOT NULL ,
  `fkSpeciesID` INT NOT NULL ,
  `fldPrior` DECIMAL(5,5) NULL ,
  `fldPriorDate` DATETIME NULL ,
  `fldPriorDescription` VARCHAR(45) NULL ,
  `fldPriorType` ENUM('Habitat','Date') NULL ,
  PRIMARY KEY (`fkLocationID`, `fkSpeciesID`) ,
  CONSTRAINT `fk_tblPriors_tblLocation1`
    FOREIGN KEY (`fkLocationID` )
    REFERENCES `acoustics`.`tblLocation` (`pkLocationID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION,
  CONSTRAINT `fk_tblPriors_tblSpecies1`
    FOREIGN KEY (`fkSpeciesID` )
    REFERENCES `acoustics`.`tblSpecies` (`pkSpeciesID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION)
ENGINE = InnoDB
COMMENT = 'Store site & species specific priors here.';

CREATE INDEX `fk_tblPriors_tblLocation1_idx` ON `acoustics`.`tblPriors`
(`fkLocationID` ASC) ;

CREATE INDEX `fk_tblPriors_tblSpecies1_idx` ON `acoustics`.`tblPriors`
(`fkSpeciesID` ASC) ;
```

Appendix S8.B. Database Schema (continued)

```
-- -----------------------------------------------------
-- Table `acoustics`.`tblResult`
-- -----------------------------------------------------
DROP TABLE IF EXISTS `acoustics`.`tblResult` ;

CREATE  TABLE IF NOT EXISTS `acoustics`.`tblResult` (
  `pkResultID` INT NOT NULL AUTO_INCREMENT ,
  `fkSurveyID` INT NULL ,
  `fkTemplateID` INT NOT NULL ,
  `fkPersonID` INT NULL COMMENT 'Person who performed automated detection.' ,
  `fldDateTime` DATETIME NULL COMMENT 'From findPeaks().  Time of day
corresponding to song event.  ' ,
  `fldTimeZone` CHAR(3) NULL ,
  `fldTimeS.SSS` FLOAT NULL COMMENT 'From findPeaks().  Time since beginning
of survey for song event.' ,
  `fldScore` DECIMAL(5,3) NULL COMMENT 'from findPeaks().  Peak correlation
or point matching score.' ,
  `fldHit` TINYINT(1) NULL COMMENT 'from findPeaks().  1=score>=cutoff,
0=score<cutoff.' ,
  `fldVerified` TINYINT(1) NULL COMMENT 'user added from showPeaks() or
similar function.  1=manually verified to be true positive detection,
0=manually verified to be false-positive detection.  -1=not verified.' ,
  `fldAnalysisType` ENUM('COR','BIN') NULL COMMENT 'Type of analysis.
Current choices are cross correlation (sccCor) or binary template matching
(binaryPtMatch)' ,
  `fldLikelihood` DECIMAL(4,4) NULL COMMENT 'Probability of this species
being detected with this score.  Looked up in empirical distribution.' ,
  `fldPosterior` DECIMAL(4,4) NULL COMMENT 'Likelihood of the species being
detected with this score * a prior.  Potential priors include occupancy
probability, phenological encounter probability.' ,
  `fldCutoffValue` DECIMAL(5,3) NULL ,
  PRIMARY KEY (`pkResultID`) ,
  CONSTRAINT `fk_tblSpeciesResults_tblTemplates1`
    FOREIGN KEY (`fkTemplateID` )
    REFERENCES `acoustics`.`tblTemplate` (`pkTemplateID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION,
  CONSTRAINT `fk_tblResults_tblSurvey1`
    FOREIGN KEY (`fkSurveyID` )
    REFERENCES `acoustics`.`tblSurvey` (`pkSurveyID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION,
  CONSTRAINT `fk_tblResults_tblPerson1`
    FOREIGN KEY (`fkPersonID` )
    REFERENCES `acoustics`.`tblPerson` (`pkPersonID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION)
ENGINE = InnoDB
COMMENT = 'Table to store the results of findPeaks().';

CREATE INDEX `fk_tblSpeciesResults_tblTemplates1_idx` ON
`acoustics`.`tblResult` (`fkTemplateID` ASC) ;

CREATE INDEX `fk_tblResults_tblSurvey1_idx` ON `acoustics`.`tblResult`
(`fkSurveyID` ASC) ;
```

Appendix S8.B. Database Schema (continued)

```
CREATE INDEX `fk_tblResults_tblPerson1_idx` ON `acoustics`.`tblResult`
(`fkPersonID` ASC) ;

-- -----------------------------------------------------
-- Table `acoustics`.`tblPersonContact`
-- -----------------------------------------------------
DROP TABLE IF EXISTS `acoustics`.`tblPersonContact` ;

CREATE  TABLE IF NOT EXISTS `acoustics`.`tblPersonContact` (
  `fkPersonID` INT NOT NULL COMMENT 'This field is a foreign key that is
linked to tblPerson, and references a person\\\'s PKPersonID.' ,
  `fldContactInfo` VARCHAR(45) NOT NULL COMMENT 'The value is the contact
value itself; e.g., 802-123-4567 or johndoe@gmail.com.' ,
  `fldContactType` ENUM('Work Phone','Cell Phone','Email') NULL COMMENT 'The
contact type is restricted to an enumerated list.  Options listed include
Work Phone, Cell Phone, and Email, those this can be expanded if desired.' ,
  PRIMARY KEY (`fkPersonID`, `fldContactInfo`) ,
  CONSTRAINT `fk_tblPersonContact_tblPerson1`
    FOREIGN KEY (`fkPersonID` )
    REFERENCES `acoustics`.`tblPerson` (`pkPersonID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION)
ENGINE = InnoDB
COMMENT = 'Contact info, including Cell/Work Phone and email.  Use xxx-' /*
comment truncated */;

-- -----------------------------------------------------
-- Table `acoustics`.`tblEvironmentalData`
-- -----------------------------------------------------
DROP TABLE IF EXISTS `acoustics`.`tblEvironmentalData` ;

CREATE  TABLE IF NOT EXISTS `acoustics`.`tblEvironmentalData` (
  `pkEnvironmentalData` INT NOT NULL ,
  `fldType` ENUM('WindSpd','AirTemp','SkyCode','AtmosPress') NULL ,
  `tblCardRecorder_pkCardRecorderID` INT NOT NULL ,
  PRIMARY KEY (`pkEnvironmentalData`) ,
  CONSTRAINT `fk_tblEvironmentalData_tblCardRecorder1`
    FOREIGN KEY (`tblCardRecorder_pkCardRecorderID` )
    REFERENCES `acoustics`.`tblCardRecorder` (`pkCardRecorderID` )
    ON DELETE NO ACTION
    ON UPDATE NO ACTION)
ENGINE = InnoDB;

CREATE INDEX `fk_tblEvironmentalData_tblCardRecorder1_idx` ON
`acoustics`.`tblEvironmentalData` (`tblCardRecorder_pkCardRecorderID` ASC) ;

SET SQL_MODE=@OLD_SQL_MODE;
SET FOREIGN_KEY_CHECKS=@OLD_FOREIGN_KEY_CHECKS;
SET UNIQUE_CHECKS=@OLD_UNIQUE_CHECKS;
```

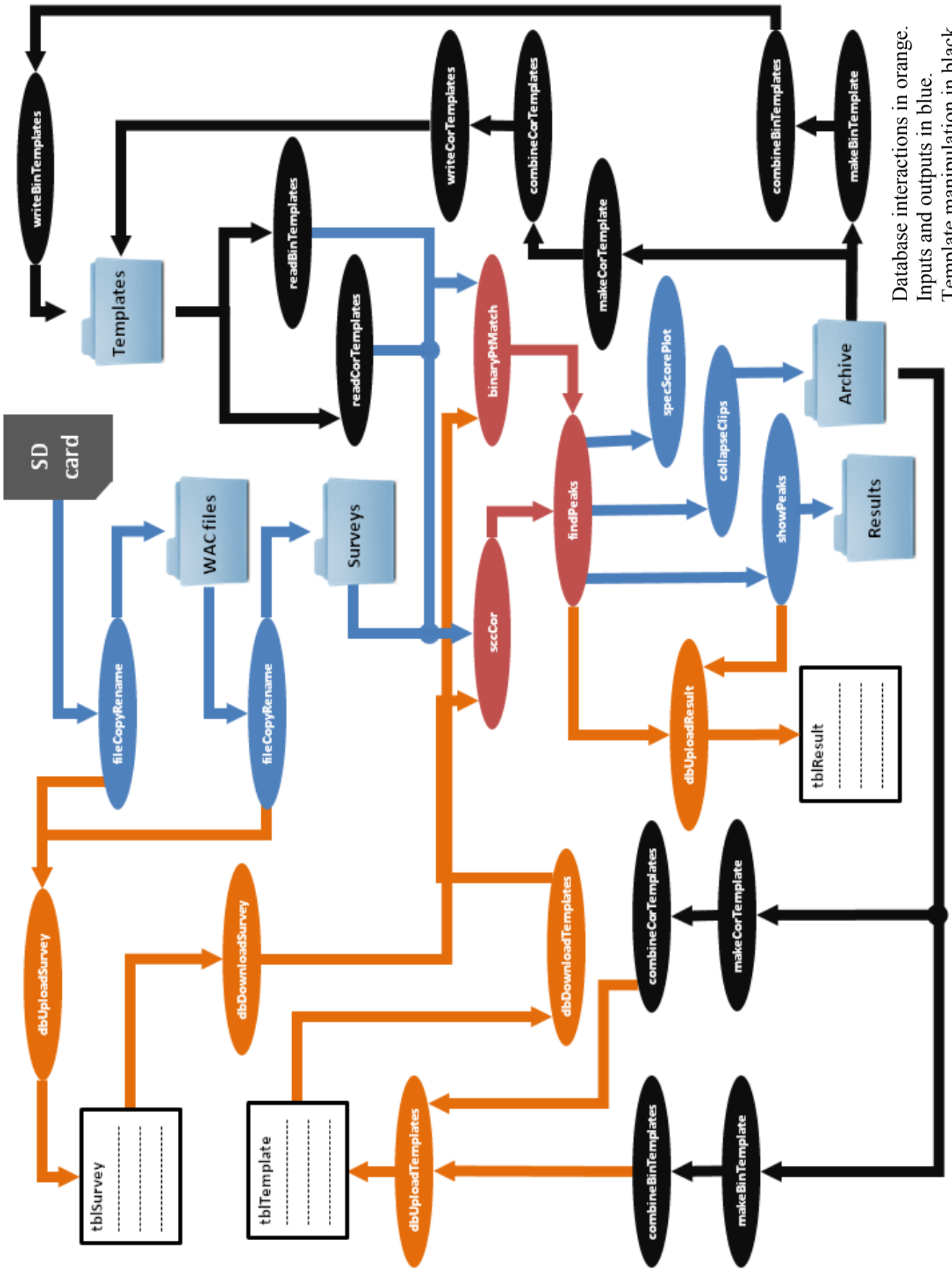
Appendix S8.C. Downloading and Installing R

The latest version of R for Windows is available at http://cran.r-project.org/bin/windows/base/. Make sure that you have administrative rights to your computer, and then double-click the installer file. Run the installation using the default options; this will install the 32 bit version if you have a 32-bit operating system, and both the 32- and 64-bit versions if you have a 64 bit operating system.
Once R installs, launch the program and select Packages… Set CRAN Mirror. A window will open, select the location nearest to you.
Select Packages… Install Packages. In the window that appears, select all the packages you might need (hold down the "Ctrl" key to select multiple packages) and click "OK":

1. tuneR
2. plyr
3. RODBC

When asked if you'd like to use a personal library, click "Yes", and allow R to create the personal library, if needed. R will download the packages.

Appendix S8.D. Analytical Flow Chart



SOP 9 – Selecting, Deploying and Maintaining Automated Digital Cameras

Northeast Temperate Network
Version 1.10

Overview

Digital timelapse photography can be an important data source for long-term phenological research, providing a consistent and objective stream of data at optimal frequency in both accessible and remote locations. This SOP describes procedures for selecting, deploying and maintaining automated digital cameras for long-term phenological observation of individual plants and vegetation canopies.

Selecting a digital camera

Comparison of a variety of camera types of varying price and quality showed little difference in ability to detect phenological trends among image datasets collected using inexpensive, outdoor webcams (cameras directly addressable via Internet Protocol) and game and plant cameras (basic time-lapse cameras targeted at hobbyists for outdoor use; herein called plant-cams), and images taken by more expensive webcams and digital single lens reflex cameras (Sonnentag et al. 2012). For this protocol, NETN uses both outdoor webcams and plant-cams.

The choice between an outdoor webcam or a plant-cam for a specific site is made by park personnel considering the availability of site infrastructure, user skills, and to some extent, cost. Webcams require an external power supply and computer-network infrastructure at the monitoring site, and also require some degree of user skill or previous experience in networking and photography. Alternatively, plant-cams are less expensive than webcams, and rely on batteries for power and memory cards for image storage. Plant-cams can be placed anywhere and operated by users with minimal training, but must be visited periodically to download images and replace batteries.

Webcams designed primarily for *indoor* use did not perform adequately in pilot testing and are not used as part of this SOP.

Choice of specific camera model will vary depending upon budget and availability. Recommended plant-cams include Wingscapes PlantCam (model WSCA04; no longer available for purchase as of spring 2013) and Wingscapes TimelapseCam 8.0 (model WSCT01; about $100). The TimelapseCam has higher photo resolution and more flexibility for photo scheduling than the former, but no laser aiming feature. Recommended outdoor webcams include models from the StarDot NetCam, Axis and Vivotek product lines; for these webcams, cost of camera and accessories will be $500-$1000 or more. In particular, StarDot has been responsive to designing webcams that meet the needs of scientific professionals, such as by working to incorporate metadata into image files. Other makes and models of cameras designed for *outdoor* use may be selected for use with this SOP.

Camera housing and accessories

Plant-cams such as the Wingscapes models typically incorporate weatherproof housing as part of the unit. If so, no additional housing is needed. Despite being designed for outdoor use, outdoor webcams will likely need additional weatherproof housing installed. Pilot testing successfully used inexpensive Vitek VT-EH10 camera enclosures (approx. $25).

The Wingscapes outdoor camera mounting bracket (approx. $10) is useful for mounting Wingscapes plant-cams. Wingscapes PlantCams use external SD memory cards and batteries (4 AAs for TimelapseCam). This SOP recommends using rechargeable batteries; high capacity batteries should last approximately one month. At high resolution, the WSCA04 will store 750 photos per GB (enough for 15 days per GB if photos are taken every 30 minutes around the clock). The WSCT01 will store about 450 photos per GB at its highest resolution, for about 10 days per GB. Therefore a 4 GB card should be sufficient to match the maximum deployment length with AA batteries. For longer deployments, a solar power option is available from Wingscapes (about $80).

Aiming and mounting the camera

Cameras are used to monitor individual plants as well as vegetation canopies. Images from individual plant monitoring are analyzed for leaf "greenness" and/or flowering phenophases. For monitoring individual plants, the camera is aimed at the plant or plants of interest (of a species selected from the park's list of monitored species in a particular habitat). Plants growing in the sun will provide more consistent illumination and image quality. The camera field of view may be set to contain the entire plant (for a small plant) or a section of the plant (i.e., a specific branch of a tree), and should be consistent with the field of view from prior years. Consider future plant growth and allow space for growth within the field of view. To capture flowering phenology, consider the geometry of this species' flowering parts during camera placement (ie "nodding" flowers may best be photographed from below while upright flowers from above). The ideal setback distance from camera to plant will vary with plant size and site layout. Table S9.1 provides examples of geometric relationships between camera setback distance, camera FOV, and image resolution to assist in camera placement. If possible, the camera should point north to minimize maximize illumination by the sun and minimize lens flare.

Table S9.1. Example of geometric relationships between camera field-of-view (FOV), image size, area covered and pixel resolution, at two camera setback distances, for StarDot NetCam IR camera and Wingscapes PlantCam and TimelapseCam.

Camera	Format	FOV (degrees)	Image width (pixels)	Camera setback: 2 m (Wingscapes); 25 m (StarDot)		Camera setback: 5 m (Wingscapes); 100 m (StarDot)	
				Total FOV (m)	Pixel size (cm)	Total FOV (m)	Pixel size (cm)
Wingscapes PlantCam	Medium	52	2048	1.6	0.1	4	0.2
Wingscapes TimelapseCam	Wide HD	40	1920	1.3	0.1	3	0.2
StarDot NetCam	Regular	37	1300	15	1	60	5
StarDot NetCam	Wide	94	1300	25	3	100	13

For monitoring "greenness" of a vegetation canopy, the camera is mounted at a location offering a vantage of the canopy, such as an overlook or a tower. The field-of-view must show more canopy than sky (an ideal ratio is 80% canopy and 20% sky). Adjust zoom, if necessary, to achieve this balance. If possible, camera should be mounted 5-10 m above the canopy and looking slightly downward at approximately 10-20°. Also, cameras should be mounted pointing north, to minimize light interference from the sun and forward scatter. It is important that the area within the camera's field-of-view that automatically adjusts exposure be aimed at the canopy, not at the sky. Figure S9.1 shows an ideal field-of-view for monitoring a canopy at Harvard Forest.

Figure S9.1 Ideal field-of-view for monitoring a canopy at Harvard Forest.

Install webcams within weatherproof housing as directed by instructions for your specific model. Remember to remove the camera's lens cap before installing the camera. Slide the camera forward in its housing, so the lens is almost touching the window, to minimize the potential for reflections and glare.

Plant-cams and webcams are mounted firmly to minimize shifts in field of view. Wingscapes plant-cams have two standard tripod nuts embedded in the camera case, and can be mounted on a pole or stake using the Wingscapes outdoor camera mounting bracket (see above under Camera housing and accessories) or on a tripod, or strapped to a tree.

Connecting webcams

For webcams, plug the ethernet and power extension cables into the ports on the camera[1], and into the site's power supply and LAN router. Check to make sure the camera is on. Then, install the webcam software tools for your model on your computer. Check to see if the camera is detected and note the camera's IP address. Enter this IP address into your internet browser's address bar; a page should load with a blue background and a live image from the camera. Depending on your network, the IP address assigned to the camera may change periodically; if this happens, re-run the webcam software tools program to verify the IP. Specific instructions for connecting the Stardot NetCam SC are provided by the PhenoCam network in PhenoCam Installation Instructions by Cory Teshera-Sterne et al. (updated April 2012; available at http://phenocam.sr.unh.edu/webcam/tools/).

[1] For StarDot webcams, the ethernet must be plugged in before the power cable.

Deployment metadata

When a camera is deployed, collect camera metadata documenting the camera, site, target image and setup, as shown in Appendix S9.A. Use the camera serial number to uniquely identify each camera. Label each camera with a sticker identifying the organization deploying the units, a request not to tamper with units, a contact phone number, and, if desired, the NETN web page for phenology monitoring for people interested in more information:

http://science.nature.nps.gov/im/units/netn/monitor/programs/phenology/phenology.cfm.

Reference panels

Reference panels are used for two purposes. First, periodic photographs of a color standard card are used to verify the camera's color balance settings and to facilitate comparisons between cameras. Second, a simple matte gray reference panel is included in the corner of each image, in order to monitor both day-to-day shifts in color balance (due to changes in weather conditions) and to evaluate long-term stability of the imaging sensor.

The first objective is met by taking pictures of a ColorChecker card (Figure S9.2) under full-sun mid-day conditions (*Note: the conditions under which the ColorChecker picture is taken are very important!* Standardization is most easily obtained under full-sun conditions at mid-day). The ColorChecker card is held in front of the camera, and should fill as much of the field of view as possible. This is done when a camera is first deployed to provide camera-specific baseline data. It is done again each year at the start and end of the growing season. Pictures of the ColorChecker card are considered an important part of a camera's metadata, and these images are re-named and stored in a separate directory to facilitate identification and subsequent analysis.

The ColorChecker is not weatherproof and should not be deployed with the camera. It is kept indoors (in a protective sleeve provided for this purpose), and brought out only for camera verification. Care must be taken to protect the card from water, dirt, oils, and other sources of degradation.

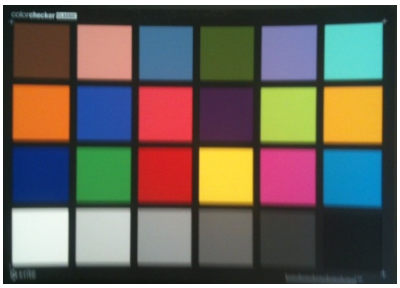


Figure S9.2. X-Rite ColorChecker Classic card used to verify camera color balance and sensitivity prior to and during field deployment. The card is available online for about $70 at B&H Photo, see www.bhphotovideo.com/c/product/465286-REG.

PhenoCam Image Processor (PCIP) software is used to determine the color (as R, G and B values) of different squares in the ColorChecker card. Instructions for downloading and using this software are found in SOP 10 – Processing Image Data. Alternatively, the Macintosh OS utility, "Digital Color Meter", can easily perform this color determination. The (R,G,B) values

for a selection of squares in the ColorChecker are recorded as metadata for each camera, as shown here:

ColorChecker Square Date	Row	Col.	Color	R	G	B
8 May 2013	2	2	blue	28	56	140
8 May 2013	2	5	green	170	210	70
8 May 2013	3	4	red	197	10	26
8 May 2013	3	5	pink	208	40	117

To compare two cameras, for camera A assume that the blue square in column 2, row 2, has a color of (R_A, G_A, B_A), while for camera B the same square has a color of (R_B, G_B, B_B). Then, color data for a vegetated region of interest from camera A can be re-scaled to match the color balance of camera B by multiplying the red channel by (R_B/R_A), the green channel by (G_B/G_A) and the blue channel by (B_B/B_A). Note that this re-scaling is not strictly necessary for successful analysis, and re-scaling can be applied at a later time as long as the metadata described above are available.

To check changes in the camera's color sensitivity over time, e.g. consider A and B not as different cameras but as measurements at the start and end of the growing season. In this case, the analysis focuses on changes in the relative sensitivity of R, G and B color channels, e.g. R to G, G to B, or R to B. If any of the ratios $(R_A/G_A)/(R_B/G_B)$, $(G_A/B_A)/(G_B/B_B)$, or $(R_A/B_A)/(R_B/B_B)$ are < 0.9 or > 1.1, then the camera is a candidate for replacement, as shifts over time in the sensitivity of different color channels will make data interpretation challenging.

The second objective of monitoring day-to-day variability is met by mounting a small reference panel in the camera's field of view so that the panel is included in every picture (Figure S9.3). Unfortunately, changes in illumination geometry, and the effects of this on panel brightness and apparent color, make it difficult to use the reference panel as a true standard (i.e. that can be used for post-hoc calibration or correction), but the reference panel is nevertheless important as a means of verifying day-to-day camera functionality.

The reference panel is easily made from a Carlon rectangular plastic electrical box cover (Available at http://www.lowes.com/pd_130189-223-HB1BL_0_), spray painted with matte gray primer (e.g., Rust-Oleum 12 Oz. Gray Primer Flat Spray Paint, http://www.lowes.com/pd_89137-90-1680830_0_). The panel is re-painted annually.

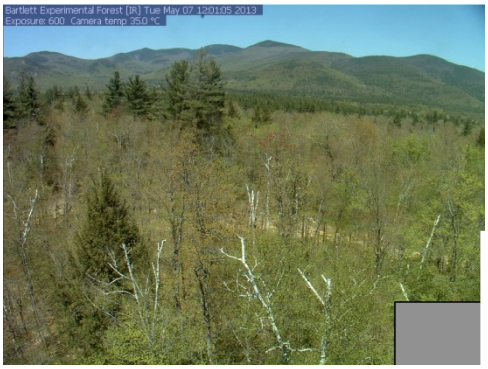


Figure S9.3. Sample image showing grey reference panel included in the camera field of view. Verify that the panel is at least 20x20 pixels in size.

For aerial cameras (mounted on towers, building roofs, etc.), mount the panel on a horizontal pole on an adjustable mount (such as a U Bolt) at a distance of about 3' from the camera to panel. One drawback of this method is that the panel will not always be illuminated the same as the canopy at which the camera is pointed. For ground-mounted cameras, mount the panel on a vertical pole as close as possible to the vegetation of interest. Verify that the size of the panel in the image is no smaller than 20 x 20 pixels. In both cases, the panel is mounted vertically.

The reference panel is included as a region of interest when analyzing images for seasonal changes in vegetation green chromatic coordinate (g_{cc}) using PCIP software. The g_{cc} of the reference panel should be ≈ 0.33 (indicating a grey that is an equal mix of red, green and blue) throughout the year, and should not show obvious seasonality.

Digital camera settings

Most configuration settings are kept on default or automatic settings. One exception is that "white balance" (sometimes referred to as "color balance") is set manually to the "fixed" setting (sometimes referred to as "manual" or "outdoor" settings) for webcams, if possible, in order to minimize in-camera processing of day-to-day changes in illumination.[2] For TimelapseCam, set white balance to "SUNLIGHT". Set date and time settings to local standard time on plant-cams before initial use. Avoid using daylight savings time. Specific settings for the Stardot NetCam SC are included in PhenoCam Installation Instructions by Cory Teshera-Sterne et al. (updated April 2012).

Imprinting options for date, time or camera are used if available on the specific camera. For example, TimelapseCam should be set to imprint camera name, date and time on each photo.

Focusing

Adjust focus manually, if possible[3], to obtain a sharp image; it may be helpful to focus on a specific object in the image, such as a branch. For plant-cams, capture and examine a test image onsite (using a laptop or digital frame); then adjust focus as needed. Wingscapes sells an $80 accessory for viewing photos.

Mounted and aimed webcams are focused on a sunny day with a nearby laptop connected to the camera's configuration pages. Specific instructions for focusing the Stardot NetCam SC can be found in PhenoCam Installation Instructions by Cory Teshera-Sterne et al. (updated April 2012).

Frequency of images

Canopy images are recorded at least every 30 minutes, from 04:00 – 20:00 hours (i.e., 4 am to 8 pm). This frequency is designed to optimize the dataset for canopy analysis using PhenoCam methods which use a 3-day moving window (Sonnentag et al. 2012). Since day length varies

[2] Terminology for these settings varies among camera brands.
[3] TimelapseCam has manual focus. PlantCam does not.

over the course of the season, some images before and after the summer solstice will be taken at night. These dark images are very small (in terms of storage space) and are easily filtered out of the dataset prior to analysis.

Plant-cams or other digital cameras aimed at individual plants record images hourly from 8 am to 5 pm (for a total of 10 images per day). For plant-cams, in the Setup Menu, set Time Lapse Interval to be "1 HOUR," and make sure Photo or Video? option is set to "Photo."

Image file format, size and filename

There is always a trade-off between resolution and file storage, because higher resolution images use more storage space. Current recommended file resolution is 1 megapixel.[4] For example, a digital image that is 1024 x 768 is approximately 1 MP. For Wingscapes plant-cams, choose photo quality to be WIDE HD (1920 x 1080), or HIGH (2592 x 1944) for TimelapseCam; choose MEDIUM (2048 x 1536) for PlantCam. Images are saved as JPEG files.

Image file naming follows this format: PARK####_YYYY_MM_DD_HHMMSS.jpg, where PARK is the four-letter park acronym and #### is the four-digit USA-NPN site number. YYYY_MM_DD_HHMMSS is the date and time the photo was taken. For cameras which do not allow custom file naming (such as TimelapseCam), images are renamed immediately after downloading using Bulk Rename Utility software, as described in Appendix A of SOP 11 - Data Management and Quality Assurance/Quality Control.

Maintenance and troubleshooting

Plant-cams are visited about 1 week after initial deployment, to ensure that the camera is still aimed and functioning properly. Thereafter, plant-cams are visited periodically to change batteries and memory cards. Rechargeable batteries and memory cards are given unique numbers and labeled with a permanent marker to aid in trouble-shooting. Maintenance datasheets (Appendix S9.A) are completed at each visit.

Webcam IP's are checked at least weekly to ensure that images are updating regularly, that the window is not dirty or obscured, and that the camera field of view is still as desired (e.g., the housing has not shaken loose). Many problems can be fixed simply by temporarily unplugging the ethernet cable to the camera and at the same time cycling the camera's power (i.e., shut the power off and then turn power back on). It is also useful to check the status lights for the camera and LAN router sockets. Specific instructions for maintaining and trouble-shooting the Stardot NetCam SC are included in PhenoCam Installation Instructions by Cory Teshera-Sterne et al. (updated April 2012).

[4] Calculated by multiplying by image width in pixels by image length in pixels.

Literature Cited

Sonnentag, O., K. Hufkens, C. Teshera-Sterne, et al. 2012. Digital repeat photography for phenological research in forest ecosystems. Agricultural and Forest Meteorology 152:159-177.

Teshera-Sterne, C., et al. 2012. PhenoCam Installation Instructions. https://dl.dropbox.com/u/29219356/PhenoCam_Install_Instructions.doc

Revision History

Version #	Date	Revised by	Changes	Justification
1.00	May 2012	Geri Tierney	Adapted from: Digital repeat photography for phenological research: camera deployment and image processing protocol (Sonnetag and Richardson, June 2011); PhenoCam Installation Instructions (Teshera-Sterne and Richardson, May 2011); and Wingscapes Timelapse Camera User Guide (2010). Added reference panel description from Andrew Richardson.	
1.01	Oct 2012	Geri Tierney	Added filenaming guidance and specific settings for TimelapseCam.	
1.02	Nov 2012	Andrew Richardson, Michael Toomey, Geri Tierney, Steve Klosterman	Replaced Appendix B with reference to PhenoCam document. Included file naming procedure. Editorial comments.	
1.10	May 2013	Geri Tierney, Michael Toomey, Andrew Richardson	Reduced frequency of images from plant-cams and other cameras aimed at individual plants. Clarified need for frequent images for canopy photos. Added table relating camera FOV, image size, distance to target and resolution. Added metadata collection sheet. Revised reference panel procedure now uses simple grey panel. Check with Andrew Richardson in 2014 re: ongoing research on reference panels.	Response to review. Reference panel procedure revised as per A. Richardson's ongoing research.

Appendix S9.A. Camera Deployment Metadata

Equipment:
Camera(s)
Writing utensil
Empty SD cards
Charged batteries
Camera housing (for webcams)
Laptop (for webcams)
Mounting bracket (optional for Wingscapes plant-cams)
Mounting pole, tripod or straps (for Wingscapes plant-cams)
Colorchecker card
Reference panel with mounting hardware
Tools for mounting

Date:_____ Location/Park: _____ Site #:_____

Lat:_____ Long: _____

Camera make/model:

Camera serial or unit number:

View target (canopy or plant):

Plant species in view:

Monitored plant ID (if any):

What direction is the camera pointing (north is preferred)?

For webcam, what is the internet connection and camera address?

What power source or specific battery type does this camera use?

Appendix S9.B. Sample Plant-cam Maintenance Datasheet

Equipment:
Writing utensil
Empty SD cards
Charged batteries

Date:_____ Location/Park: _____ Site #:_____

Lat:_____ Long: _____

Unit #	Empty/Taken Out		Full/Put In		Notes
	SD Card	SD Card	Battery	Battery	

Plant-cam checklist

___ Replace batteries
___ Replace SD cards
___ Record SD card and battery numbers in datasheet
___ Check the unit and cables over for any damage or needed adjustments
___ Remember to shut all units and battery cases

SOP 10 – Processing Image Data

Northeast Temperate Network
Version 1.03

Overview

Digital timelapse photography can be an important data source for long-term phenological research, providing a consistent and objective stream of data at optimal frequency in both accessible and remote locations. This SOP provides specific procedures for processing digital image files to track seasonal development of individual plants and vegetation canopies. Red-green-blue (RGB) color channel information is extracted and transformed to green chromatic coordinate (g_{cc}) as an indicator of canopy greenness which is tracked over time. This analysis is performed on image datasets collected from outdoor netcams and plantcams maintained by NETN, as well as on image datasets collected from various cameras by volunteers at NETN designated photopoint sites. Analysis is performed using PhenoCam Image Processor, a stand-alone software program developed by Koen Hufkens. In future work, we plan to incorporate methods for scaling-up to connect this dataset to satellite imagery. In addition, we are developing procedures to track development of flowering and other phenophases in image datasets.

List of Key Acronyms

DN – digital number
g_{cc} – green chromatic coordinate
PCIP – PhenoCam Image Processor software
RGB – red, green, and blue
ROI – region(s) of interest

PhenoCam Image Processor (PCIP)

PhenoCam Image Processor is a stand-alone software program built using Matlab functionality. PCIP can run on computers without a licensed Matlab copy using Matlab Compiler Runtime (MCR) provided with the PCIP installer.

PCIP (also called PhenoCam GUI) can be downloaded from the website http://phenocam.sr.unh.edu/webcam/tools/, or obtained from NETN staff. To install and run PCIP, follow the instructions 'Installing and Using Phenocam' that comes with the software download.

Selecting regions of interest (ROI)

For tracking seasonal development of greenness in individual plants, we select a region of interest within each image dataset, comprised almost entirely of leaves of that plant. Additional ROIs may be selected for other plants or species represented in the same image dataset. For tracking vegetation canopies, we select one to three ROIs that are representative of the dominant species of vegetation in that region. It is important the ROI be large enough that any minor shifts in the field of view over time will not substantially alter the delineated region. For example, the ROI should fall within an area bordered by enough foliage that a minor shift in field of view will not shift the ROI off the foliage.

ROIs are selected and saved using the analysis software program, as described in the document 'Installing and Using PhenoCam'. It is very important to save the ROI from each analysis so that they may be used to designate the same region when analyzing images from this site in subsequent years.

Calculating g_{cc}

Long-term datasets of repeat images taken hourly for several months or several years show scene illumination changes due to the daily rotation of the Earth, the Earth's revolution, cloudiness and other changes in overall weather conditions. This variation is unrelated to the variable of interest – canopy greenness. To suppress the influence of these scene illumination changes on time series of canopy greenness we follow the procedure recommended by Sonnentag et al. (2012) and calculate green chromatic coordinate as:

$$g_{cc} = G/[R+G+B]$$

where R, G and B represent, respectively, red, green and blue digital number (DN)

We use PCIP to extract RGB DN within the region(s) of interest.

As a quality check at sites where vegetation canopies are monitored, we select an additional ROI covering the reference panel, and calculate g_{cc} for the reference ROI. The g_{cc} for the reference panel should be essentially stable over time. It may be variable from day to day, because of weather and clouds, but there should be no long-term or seasonal trend in the g_{cc} of the reference panel. If a trend is detected in g_{cc} for the reference panel ROI, this trend must be taken into account during analysis of data from this camera, and both the camera and reference panel should be carefully examined for degradation.

Filtering night-time images

Night-time images are excluded from analysis in PCIP by filtering-out "dark" images from around sunrise or sunset by simple *RGB* thresholding. To do so, ROI-averaged *RGB* triplets (sets of R, G, and B DN) below a predefined threshold are discarded. This threshold is typically set to 15% of maximum DN (i.e., full sun), but in some cases the level may be set lower to avoid data gaps. In pilot testing using webcams, a threshold of 10% was needed in some areas with very high contrast causing deep shadows in order to avoid multi-day gaps in data. If the 15% threshold results in a multi-day gap in data for a particular camera dataset, determine the appropriate threshold for that camera using this method. Examine the frequency distribution of total image brightness (calculated as the sum of R, G and B DN in the PCIP output dataset; see Figure 1 for example). The distribution is typically bimodal with some very dark images (taken at night) being one low-DN peak, and most of the daytime images forming a high-DN peak. In Figure 1, the threshold can then be set to filter out the low-DN images by choosing a data point just above the lower peak of night images, and calculating the % full sun of this data point. Calculate % of maximum DN as total brightness of this data point (sum of R, G and B DN) divided by maximum DN (256 + 256 + 256 = 768), then round to the nearest 5%.

Figure S10.1 illustrates this procedure. Note the bimodal distribution: the lower peak represents nighttime photos and the higher peak represents daytime photos. Using the breaking point, 100, we can estimate a day/night threshold of 100/768, or 13% (round to 15%) for the PICP.

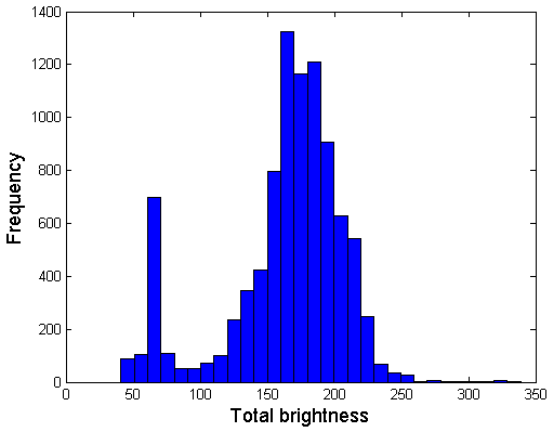


Figure S10.1. Frequency histogram of total image brightness (R+G+B) for one year of images from Harvard forest.

In PCIP, set "dark thres" in the calculation window to be 15, or to the level indicated by analysis of the frequency distribution as described above.

In addition, PCIP allows the user to select minimum and maximum hours of image to include in analysis. Under 'Calculation Options', choose a minimum of 4 (i.e., 4 am), and a maximum of 20 (i.e., 8 pm).

Assigning *per90*

To further reduce the influence of short-term changes in scene illumination due to weather and other factors, we use a moving window approach that assigns the 90th percentile of all daytime g_{cc} values within a three-day window to the center day (*per90*), resulting in three-day g_{cc}. For a long-term time series, a value every third day is sufficient for characterizing seasonal canopy development, and avoids the auto-correlation that would occur in a daily dataset of this type. Sonnentag et al. (2012) stress that the effectiveness of *per90* depends largely on data availability, thus high-frequency image archives are needed (ideally: one image every 30-min during daylight hours, as specified in the Selecting, Deploying and Maintaining Automated Digital Cameras SOP).

Within PCIP, select a window of 3 days, and check the box for 90th perc. (within 'Calculation Options').

Detecting phenophases

Figure S10.2 illustrates a typical g_{cc} time series, as derived from a Harvard Forest webcam with the four principal phenophases indicated below. Winter baseline values are typically in the range of 0.33 to 0.40, where lower values are expected in a 100% deciduous canopy as compared to this partially coniferous forest. Spring green-up demonstrates a very rapid increase from the baseline, 0.36 to the summer peak, 0.46. These g_{cc} values gently decline with increasing chlorophyll and aging/darkening of the leaves throughout the summer, dropping to a value of 0.42. At the beginning of fall, leaf coloration rapidly decreases g_{cc} values to a low value of 0.34, below the baseline. Leaf abscission then exposes the grayish tree trunks, which returns g_{cc} to its normal baseline of 0.36. In addition, analysis of red chromatic coordinate (r_{cc}) may be used to quantify autumn coloration.

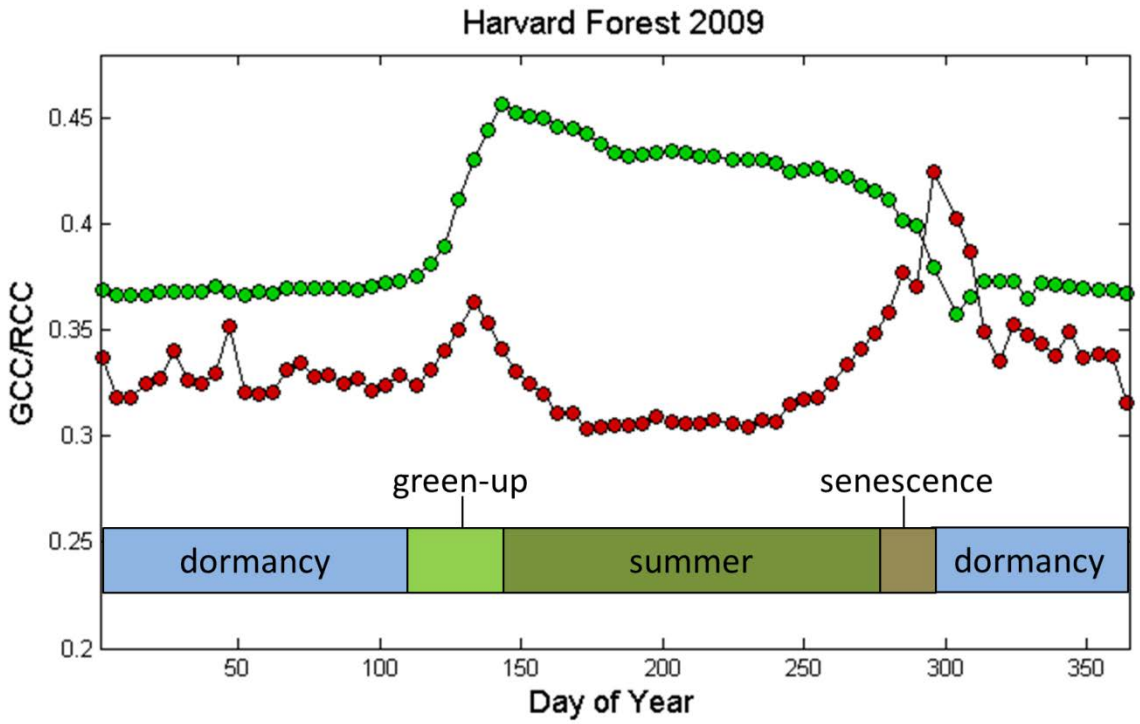


Figure S10.2. g_{cc}/r_{cc} time series from a Harvard Forest webcam in 2009.

The seasonality of greenness at evergreen-dominated forest sites in the northeast US is largely controlled by seasonal changes in chlorophyll and pigment composition of existing foliage rather than growth and senescence of new leaves. Thus NETN evergreen-dominated sites are expected to show a slightly different but still distinct phenology of change in greenness.

Analysis of phenophases for cameras aimed at individual plants

These procedures are a first draft; they will be refined as camera data is collected and personnel become available to analyze the image data.

For plants that have stable areas suitable for automated analysis of g_{cc} (primarily trees and shrubs with stable branches), the procedures described above should be used to automatically extract this information.

For other phenophases, the photos will be reviewed and the phenophases for each day with suitable photography will be recorded in Nature's Notebook. It will help to use a computer with two monitors, so that Nature's Notebook can be open on one screen for data entry, and photos can be viewed on another. The basic procedure (written for Windows XP) is as follows:

- Photos should be organized so that all photos for a given individual and year are in the same folder (see SOP 11- Data Management and QA/QC for file name conventions).
- Open an instance of Windows Explorer on one screen and maximize the application. Navigate to the folder with the correct individual and year, and change the "View" setting to "Filmstrip" (View… Filmstrip in Windows XP). Shrink the size of the file navigation pane if needed to enlarge the photo so plant phenology can be easily viewed.

- Open an instance of Nature's Notebook on the other screen, log in, and open a data entry form for the individual. Alternatively, print out a data form and record data on the form, then follow up with entry on-line.
- Starting with the earliest photo (the left-most photo if the photos have been named properly), evaluate one photo per day for phenology and record the data in Nature's Notebook.
    - Make sure to use the correct individual (or portion of individual or patch of individuals; the "focal area") for recording data, and never change the focal area over the course of a season of data without noting this in Nature's Notebook (some changes will require setting up a new individual or patch in Nature's Notebook).
    - It will help to quickly scan through the photo data (beginning, mid-season, and end) to ensure that the camera view did not shift and lose part of the focal area.
    - If recording data from a partial individual (e.g., a tree branch), make sure this is recorded in Nature's Notebook.
    - Start with the photo taken as close to noon as possible on the first day of monitoring. If that photo is blurry or dark, use the closest photo to noon that allows you to see the plant phenology.
    - If the filmstrip view does not allow you to see phenophases adequately, double-clicking on the image thumbnail at the bottom of Windows Explorer will open the default photo program on your computer; that program should allow you to zoom in on sections of the photo.

Literature Cited

Sonnentag, O., K. Hufkens, C. Teshera-Sterne, et al. 2012. Digital repeat photography for phenological research in forest ecosystems. Agricultural and Forest Meteorology 152:159-177.

Revision History

Version #	Date	Revised by	Changes	Justification
1.00	May 2012	Geri Tierney, Andrew Richardson	Adapted from: Digital repeat photography for phenological research: camera deployment and image processing protocol (Sonnentag and Richardson, June 2011); and Digital repeat photography for phenological research in forest ecosystems (Sonnentag et al, 2012)	
1.01	Oct 2012	Geri Tierney, Michael Toomey	Added procedures for running PCIP software.	
1.02	Nov 2012	Brian Mitchell, Geri Tierney, Andrew Richardson, Michael Toomey, Steve Klosterman	Added procedures for evaluating photo data with an observer, for cameras aimed at individual plants. Added procedure for selection of darkness threshold. Editorial changes.	
1.03	May 2013	Geri Tierney, Michael Toomey	Noted future plans to scale-up to connect this dataset to satellite imagery. Updated Figure 1 to show Rcc. Editorial changes.	

SOP 11 – Data Management and Quality Assurance/Quality Control

Northeast Temperate Network
Version 1.12

Overview

This SOP describes data management and quality assurance/quality control (QA/QC) procedures used to insure accurate data collection by phenology observers and automatic recording devices. Data management for three types of data is addressed in this SOP: tabular observations, digital audio files, and digital image files. Observation data are submitted to the USA-NPN National Phenology Database via *Nature's Notebook*. Audio recordings and image files collected from automatic recorders are stored by staff at participating parks on external hard drives. Raw image files also are stored on the PhenoCam server. Processed data files from automatic recorders are stored by the NETN data manager until those files can be submitted to the National Phenology Database via *Nature's Notebook*. Responsibility for data management is shared between park coordinators and the NETN Data Manager, as shown in Appendix S11.A.

Data submission

Park visitors and trained monitors submit observation data directly online at *Nature's Notebook* (www.nn.usanpn.org). The USA-NPN has created this online interface to provide a user-friendly method to record and store phenology observations and metadata. Entries into *Nature's Notebook* are stored in the National Phenology Database and are freely available for others to access.

Raw data from automated audio and camera recorders are retrieved periodically by park staff or trained volunteers as described in SOP 6 – Deployment and Maintenance of Autonomous Recording Units and SOP 9 – Selecting, Deploying and Maintaining Automated Digital Cameras SOP. After data are subsampled (only Olympus ARU data) and processed as described in SOP 8 – Automated Sound Analysis and SOP 10 – Processing Image Data, processed datasets are stored by the NETN data manager until those files can be submitted via *Nature's Notebook*. As of 2012, USA-NPN plans to expand their data submission capabilities in the future to include data from automated recorders.

Quality Assurance

To insure the quality of monitoring data collected in this program, we rely on standardized, written protocols and datasheets, careful training for monitors making repeated observations, and oversight by park-level coordinators. For digital data collection, we employ standardized file-naming procedures (see Data Stewardship below), and data imprinting on imagery for assurance that site and date metadata are correctly attached to each file.

The NETN Phenology Monitoring Protocol provides detailed instructions for training of monitors making repeated observations, site selection and setup, deployment and maintenance of audio recorders, data collection, quality assurance/quality control and data stewardship. For data collection by observers, this protocol utilizes datasheets, phenophase descriptions, and other materials developed by USA-NPN. These materials have been carefully designed to clearly and specifically describe phenophases and associated data collection for observers from diverse

backgrounds (USA NPN 2011). USA-NPN has incorporated many QA/QC measures into their procedures and their *Nature's Notebook* online interface. Online QA/QC measures include the use of carefully designed and tested menus utilizing pick lists to reduce data entry errors.

During training, all monitors making repeated observations receive explicit instructions describing how to make and report phenological observations on the species selected for observation in that park. They are also given information describing the sites at which observation occurs within that park.

Park-level coordinators provide another level of quality assurance. These coordinators select and mark sites for observation, and select or oversee selection of individual plants to be monitored. Thus species identification errors for plants are minimized. Park-level coordinators interact with observers during training and provide observer support. By doing so they are able to correct potential errors, as well as provide some insight into the skill of different observers.

Quality Control

Data validation is made by comparing phenological data from multiple methods at the same site, and at related sites (i.e., similar sites at the same park). Data collected by untrained and trained volunteers, and from automated cameras and audiorecorders will be compared to identify possible bias introduced by method, by training or lack or training, by frequency of collection, and by species or phenophase observed.

During training, park coordinators identify volunteers whose skills or experience are demonstrably higher than typical volunteers, or alternatively who are newer or less experienced than typical volunteers. Park coordinators keep a simple record of volunteer skill levels as 1) beginner; 2) typical; and 3) advanced; this record is updated annually for returning volunteers as skills improve over time. This information on observer skill level may be used during data analysis to give greater or lesser weight to data collected from higher or lower skilled observers, respectively. In order to do so, the NETN Data Manager may need to submit lists of volunteers in each class to USA-NPN NCO staff, and request a sorted list of corresponding observer identification numbers in each class. This procedure will enable NETN to consider volunteer skill level while complying with the Privacy Act.

Automated analysis will identify phenology outliers greater or equal to one month from expected dates based on the accumulated dataset. Outliers of this magnitude are typically recording errors; these outliers will be excluded from trend analysis.

Data Stewardship

Subsampled audio files from Song Meter recorders and Olympus ARUs are stored by participating parks using duplicate external hard drives. Each Song Meter ARU operating as recommended (subsample 10 minutes per hour and convert to WAV file) generates about 1.0 Gb per day of raw audio data. Each Olympus ARU subsampled as recommended in the Automated Sound Detection and Classification SOP (subsample 10 minutes per hour as MP3) generates about 0.4 Gb per day of raw audio data. Note that only the subsampled raw data are processed and stored; the remainder of the data stream is discarded.

Each webcam operating as recommended (1 MB .jpg photo captured every ½ hour for 14 hours/day) generates about 28 MB per day of raw image data. Each plant-cam operating as recommended (1 MB .jpg photo captured hourly for 10 hours/day) generates about 10 MB per day of raw image data. Image files from automatic cameras are stored by participating parks on external hard drives, and also on the PhenoCam server, as described below. On the PhenoCam server, image data are stored in monthly folders (i.e., 01 for January) within annual folders (i.e., 2012) within site folders (i.e., ACAD3191 for a camera located at ACAD site 3191).

All computer data files are stored in duplicate, to guard against data loss from hard drive failure. For most data, this is accomplished by storing identical (mirrored) copies on two separate external hard drives. For raw image files, this is accomplished by storing one copy on an external hard drive and a second copy on the PhenoCam server.

Hard drives are checked annually prior to the beginning of the field season to insure that both copies are functional. Software designed to conduct hard drive "health tests" can make testing more reliable (e.g. http://hddscan.com/). If a drive, or a drive sector, is found to be bad or failing, a new drive is purchased and contents from the remaining good drive copied to it immediately to maintain two functional copies of the data at all times. If the PhenoCam server discontinues operation at some future time, NETN will store duplicate (mirror) copies of image files to compensate.

File naming

Maintaining accurate, standardized, and informative file names plays a pivotal role in managing the large number of digital files generated by the implementation of this protocol. To insure files are named consistently the following naming conventions should be rigorously followed.

Image files

Since plantcam field cameras cannot be programmed to assign custom filenames, park staff must rename raw image files immediately after their collection from field units. Instructions on how to use the free Bulk Rename Utility software are provided in Appendix S11.B. This format is compatible with the PhenoCam Image Processor program.

Raw image files from automated cameras are assigned names as follows:
PARK####_YYYY_MM_DD_HHMMSS.jpg

Where:
PARK = the four-letter NPS acronym corresponding to the park of deployment (e.g., ACAD)
= the four-digit site number assigned by USA-NPN for the site of deployment
YYYY_MM_DD_HHMMSS = the date/time of data capture (year, month, day, hour, minute and second.

Audio files

During preparation for deployment, both Song Meter and Olympus ARU's are customized with site identification numbers as described in the Deployment and Maintenance of ARUs SOP. Song Meter ARUs assign filenames automatically using this site prefix (PARK####) entered by the user. However, Olympus ARUs cannot be programmed to assign sufficient custom filenames

and Olympus files must be renamed as soon as possible after collection. Olympus files are created with an 8-digit name consisting of ####0001 where #### is the site prefix (entered as the four-digit site number assigned by USA-NPN), followed by a four-digit number corresponding to the sequence in which the file was recorded. As soon as possible after data collection, park staff must rename Olympus files using the procedure outlined in the Automatic Sound Detection and Classification SOP or Bulk Rename Utility software (see Appendix S11. A). Note that for Olympus datafiles it is necessary to adjust the filename to properly reflect the START of data capture, not the time the file was created. This adjustment is made during file renaming by subtracting the audio file length from the file's modified date using an offset command as shown in Appendix S11.A. Song Meters automatically name files using the START time of data collection, so no adjustment is necessary for Song Meter files.

Raw audio files from Olympus (.mp3) and Song Meter (.wac converted to .wav) ARUs:
PARK####_YYYYMMDD_HHMMSS

Where:
PARK = the four-letter NPS acronym corresponding to the park of deployment (e.g., ACAD)
= the four-digit site number assigned by USA-NPN for the site of deployment
YYYY_MMDDHHMMSS = the START date/time of data capture (year, month, day, hour, minute and second.

Uploading to PhenoCam Server
Coordinators at parks collecting images upload images to the PhenoCam server as soon as possible after collection, using the instructions provided in Appendix C.

Legislative Requirements
To comply with the Privacy Act, data received by NETN from USA-NPN does not include personal information. Observers are indentified by an identification number assigned by USA-NPN.

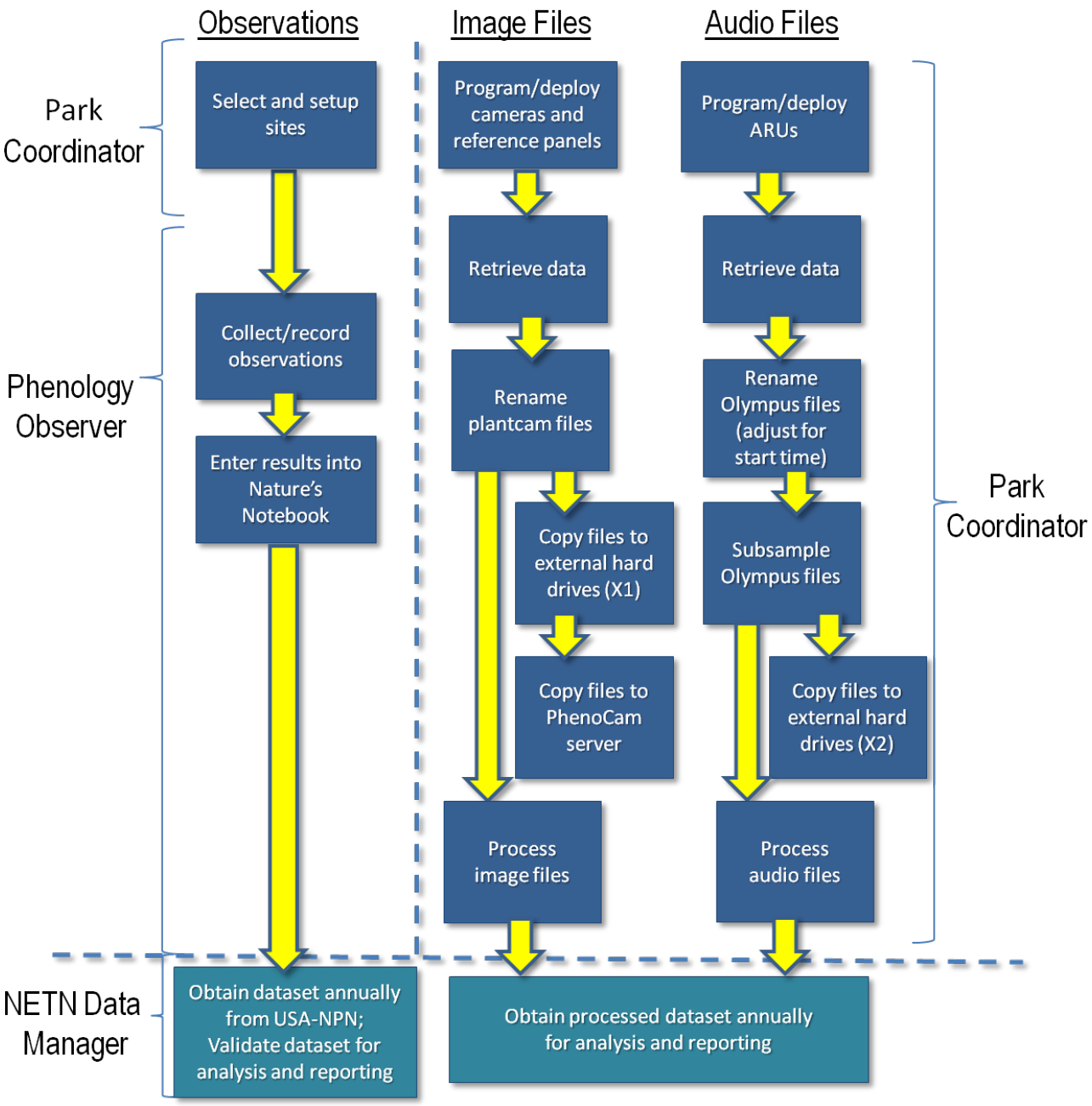
Literature Cited

USA NPN. Technical Information Sheet, Data Quality Assurance & Quality Control for *Nature's Notebook***.** Ver. 1.0, October 2011. www.usanpn.org/files/shared/files/USA-NPN_QA-QC_tech_info_sheet_3-2012.pdf

Revision History

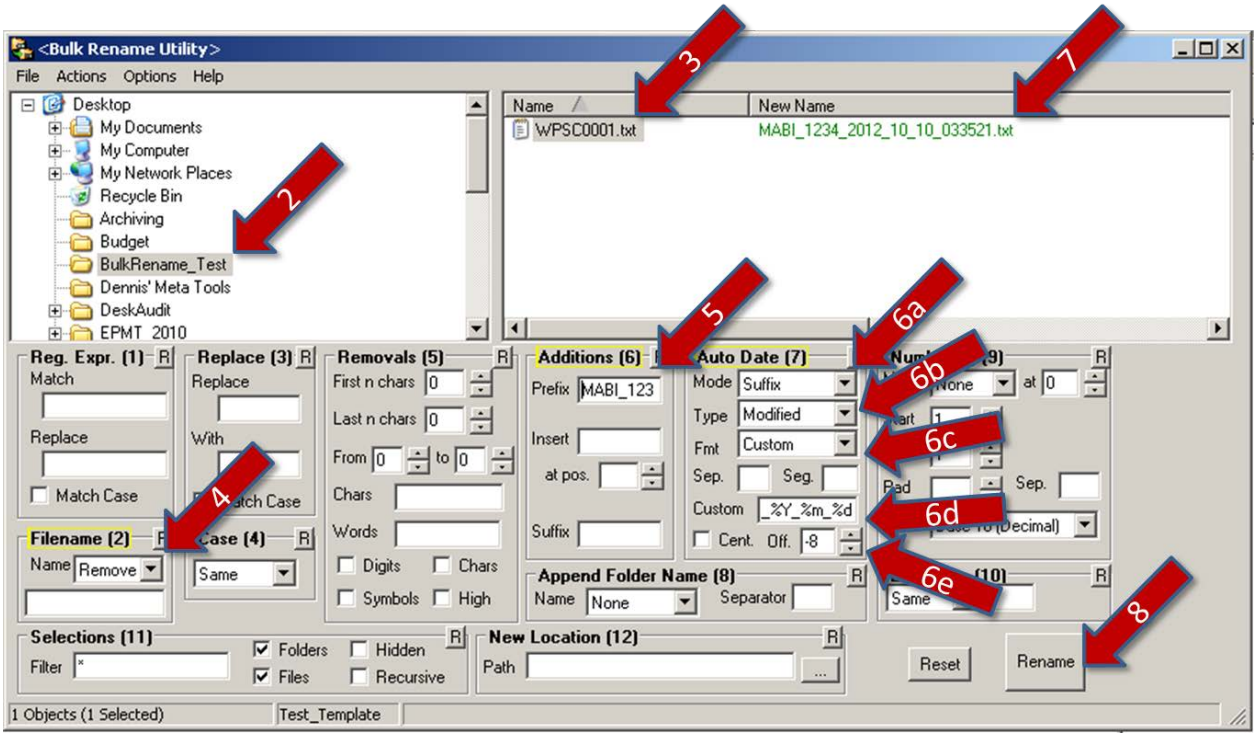
Version #	Date	Revised by	Changes	Justification
1.00	Sept 2010	Geri Tierney	Adapted from the NETN Forest Protocol Data Management and QA/QC SOP, version 2.1. Includes Privacy Act Requirements.	
1.01	Nov 2010	Geri Tierney, Adam Kozlowski	Clarification of legal requirements and data storage. Editorial changes.	
1.02	April 2011	Brian Mitchell, Geri Tierney	Clarified this SOP is for Observer data only. Eliminated custom sites. Clarified that data from one-time observers must also be stored in NPN database. Editorial changes.	
1.03	March 2012	Geri Tierney	Removed park logbook instructions.	
1.10	Jan 2013	Geri Tierney, Adam Kozlowski	Added data stewardship for automated recorder data. Added instructions for Bulk Rename Utility. Expanded QA/QC discussion. Revised to include observations by untrained observers. Revised discussion of Privacy Act compliance. Added flow chart of responsibility. Noted that SongMeter files are subsampled. Added Appendix C for uploading to PhenoCam server.	
1.11	Jan 2013	Ellen Denny, Geri Tierney, Brian Mitchell	Edited references to USA-NPN. Editorial changes..Updated Appendix C.	
1.12	May 2013	Geri Tierney, Adam Kozlowski	Editorial changes. Adjusted file renaming procedure in Appendix A to rename copies, not originals.	Response to review.

Appendix S11.A. Flowchart of Data Management Responsibility



Appendix S11.B. Using Bulk Rename Utility software

This software can be downloaded at http://www.bulkrenameutility.co.uk/Main_Intro.php



INSTRUCTIONS

1) Before starting make a copy of all the files you will be renaming.
2) Navigate to the folder containing the copies of the files you wish to rename.
3) Using the selection windows, select the file(s) you wish to rename (SHFT or CTRL + click to select more than one).
4) Set Filename to 'Remove'
5) Add the 4 letter park acronym and 4 digit site code assigned by USA-NPN (e.g. MABI1234)
6) Add an autodate
    a. Date should be added as a suffix
    b. Type = Modified* (uses the modified date stored in the file's properties)*
    c. Format = Custom
    d. For **image** files, use this custom date format = _%Y_%m_%d_%H%M%S OR For **audio** files, use this custom date format = _%Y%m%d_%H%M%S
    e. For **Olympus audio** files, offset = subtract the length of the recording (in hours)**
7) Verify for each file that the name you created matches the standardized template: PARK####_YYYY_mm_dd_HHMMSS **OR** PARK####_YYYYmmdd_HHMMSS
8) Press the 'Rename button'
9) After verifying that the files were renamed properly, delete the duplicate versions created in Step 1.

Appendix S11.B. Using Bulk Rename Utility software (continued)

* Computer files record the date/time they were Created and Modified in their properties. A file's Created Date is modified each time it is copied/moved. The Modified Date is updated when a file is opened. Since in almost all cases the files have been moved from the recording equipment's chip to a computer for renaming – the Modified Date, not the Created Date is used to establish when the recording was made.

** The file name should include the date/time that the recording started. Since the file is created by the Olympus recorder when the file is closed and saved, we must subtract the length of the recording from the Modified Date in order to obtain the start time for Olympus files only. Please refer to your deployment field sheet for each site to determine the programmed length of recording.

Appendix S11.C. Instructions for transferring images to the PhenoCam Server via FTP

Setting up a Site

Before you can transfer files your site must be set up with the PhenoCam network. For this we need some basic information about your site, including location, contacts, description of the vegetation at the site and in the field of view, etc. To do so, please fill out the survey at the following URL: http://tinyurl.com/7gd3ham

With the information included we will set up a directory for you to transfer your images. We try to use a convention for site name being a single lowercase string with no special characters (e.g. morganmonroe).

The registration and management of the PhenoCam is administered by Tom Milliman at University of New Hampshire (thomas.milliman@unh.edu). For future reference, however, problems with transmission and lost communications are mediated by Steve Klosterman at Harvard University (klosterman@fas.harvard.edu).

Image Filename Conventions

Our automated image processing requires that the filenames follow a strict naming convention which allows us to extract the image date and time from the filename. Our standard convention is:

sitename_YYYY_MM_DD_hhmmss.jpg

where,
YYYY = 4-digit year
MM = 2-digit month
DD = 2-digit day of month
hh = hours
mm = minutes
ss = seconds

We assume the date and time are for the local standard timezone. We can handle variations in the file naming convention automatically so if the standard naming convention doesn't not work for your site please contact us (thomas.milliman@unh.edu) and request an alternative.

Transferring Files

Once the site is set up and you have created appropriate file names for all photos, you will be able to transfer images via anonymous FTP to our site. For users comfortable with using the command line interface, we suggest doing so in a terminal window in UNIX-based machines, such as UNIX, LINUX, Macs or Cygwin in Windows machines. Directions are below. For those who are not, directions for using a free FTP client are below.

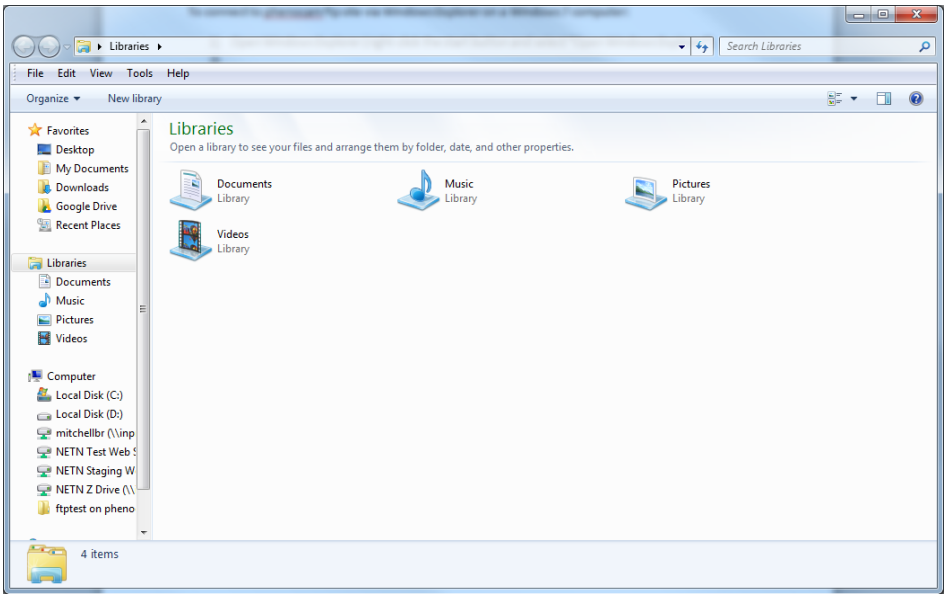
<u>Using a terminal window</u>
The URL for the ftp directory for your site will be: ftp://phenocam.sr.unh.edu/data/'sitename'/

Appendix S11.C. Instructions for transferring images to the PhenoCam Server via FTP (continued)

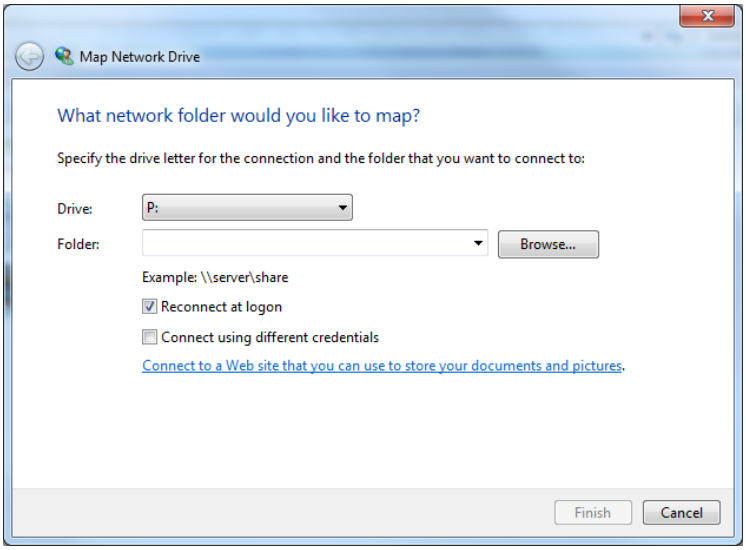
For the purposes of illustrating a transfer, we will just use a test folder called 'ftptest', or: ftp://phenocam.sr.unh.edu/data/ftptest

To connect to PhenoCam ftp site via Windows Explorer on a Windows 7 computer:

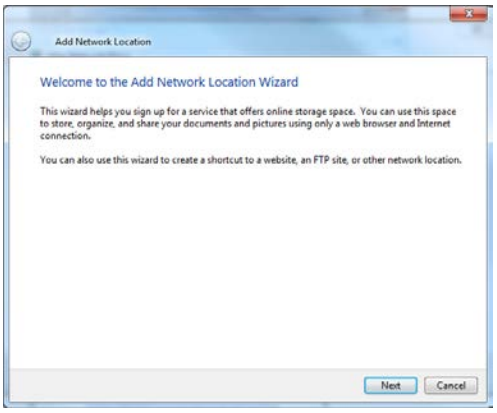
1) Open Windows Explorer (right-click the start button and select "Open Windows Explorer")



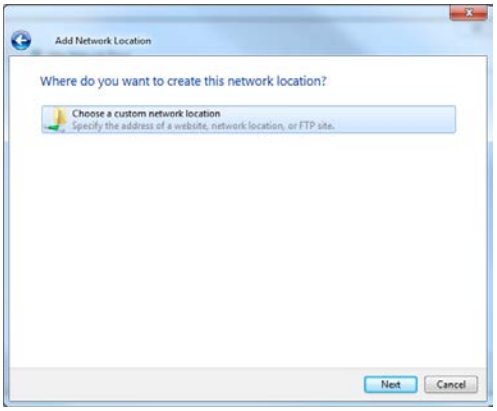
2) Select Tools… Map Network Drive


Map Network Drive
What network folder would you like to map?
Specify the drive letter for the connection and the folder that you want to connect to:
Drive:
P:
Folder:
Browse...
Example: \\server\share
Reconnect at logon
Connect using different credentials
Connect to a Web site that you can use to store your documents and pictures.
Finish
Cancel

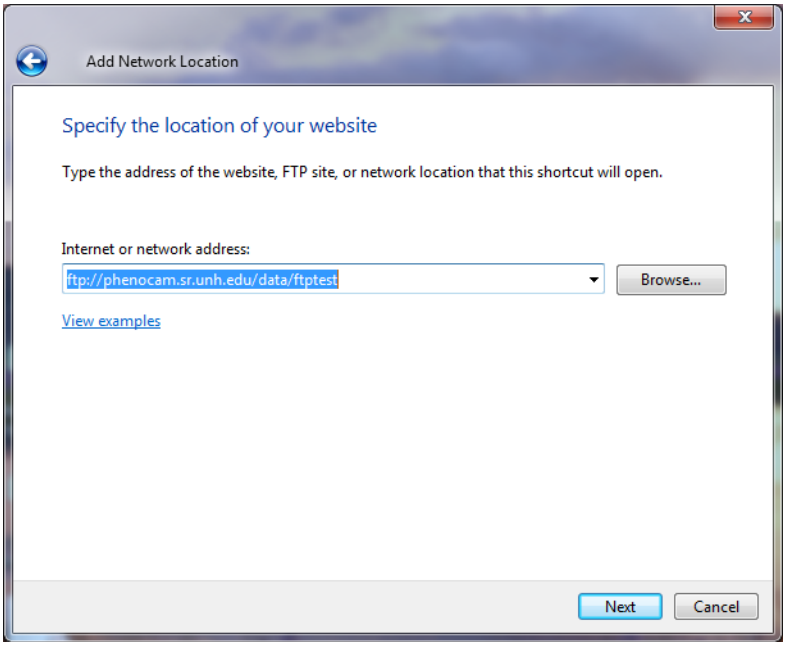
3) Click on "Connect to a Web site that you can use to store your documents and pictures."


Add Network Location
Welcome to the Add Network Location Wizard
This wizard helps you sign up for a service that offers online storage space. You can use this space to store, organize, and share your documents and pictures using only a web browser and Internet connection.
You can also use this wizard to create a shortcut to a website, an FTP site, or other network location.
Next
Cancel

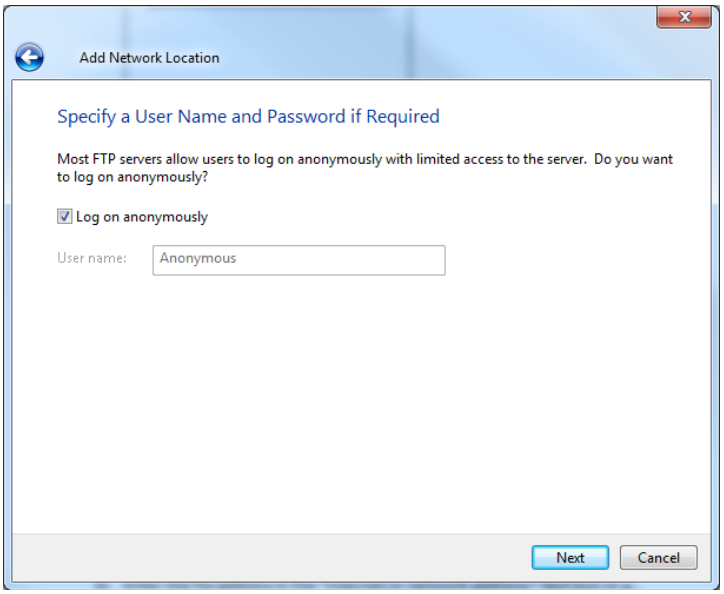
4) Click “Next”.


Add Network Location
Where do you want to create this network location?
Choose a custom network location
Specify the address of a website, network location, or FTP site.
Next
Cancel

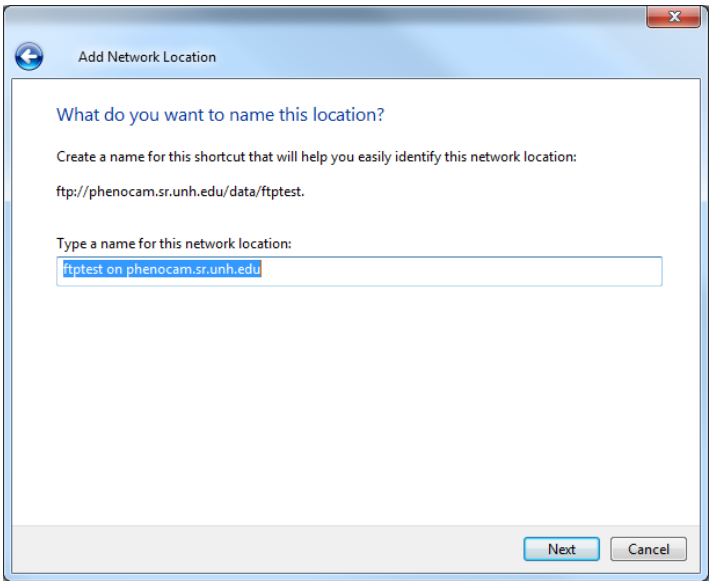
5) Click “Next”.



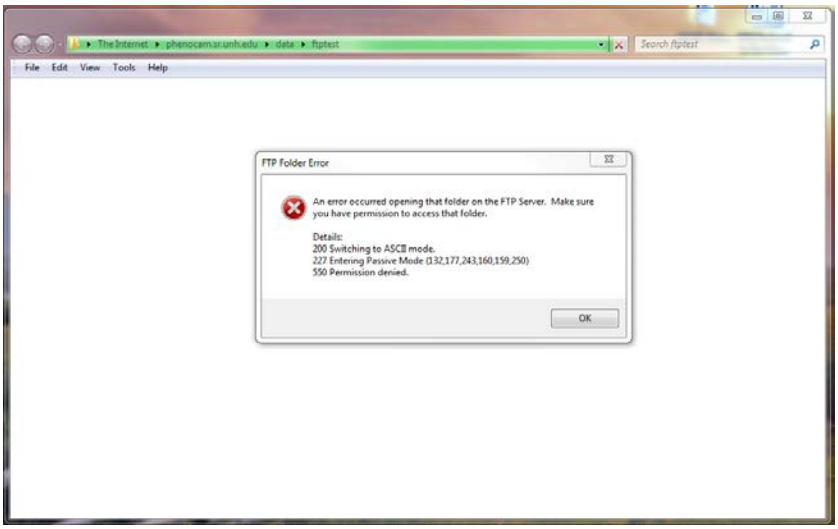
6) Enter the ftp address in the “Internet or network address:” text box (e.g., ftp://phenocam.sr.unh.edu/data/ftptest) and click “Next.”


Add Network Location
Specify a User Name and Password if Required
Most FTP servers allow users to log on anonymously with limited access to the server. Do you want to log on anonymously?
Log on anonymously
User name:
Anonymous
Next
Cancel

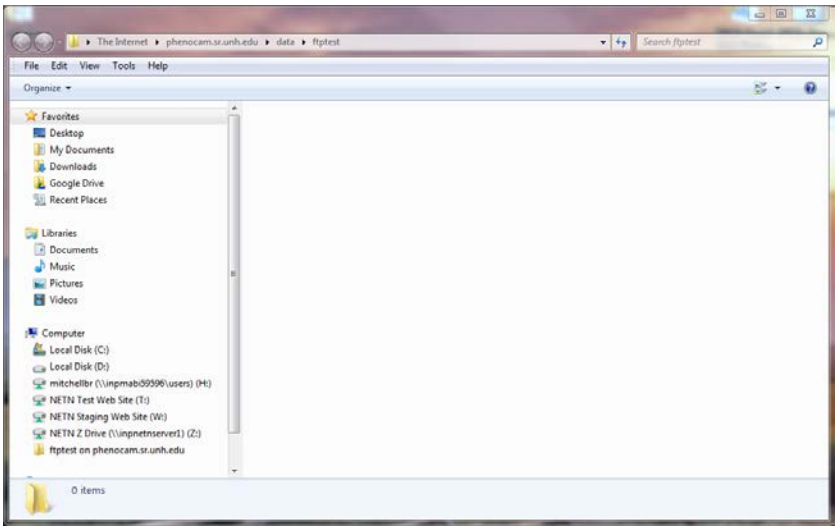
7) Click "Next."


Add Network Location
What do you want to name this location?
Create a name for this shortcut that will help you easily identify this network location:
ftp://phenocam.sr.unh.edu/data/ftptest.
Type a name for this network location:
ftptest on phenocam.sr.unh.edu
Next
Cancel

8) Rename the location if desired, and click "Next."


FTP Folder Error
An error occurred opening that folder on the FTP Server. Make sure you have permission to access that folder.
Details:
200 Switching to ASCII mode.
227 Entering Passive Mode (132,177,243,160,159,250)
550 Permission denied.
OK

9) Click "OK" to the FTP Folder Error message. The anonymous login does not have read permission, but it is possible to move files to the location despite the error.

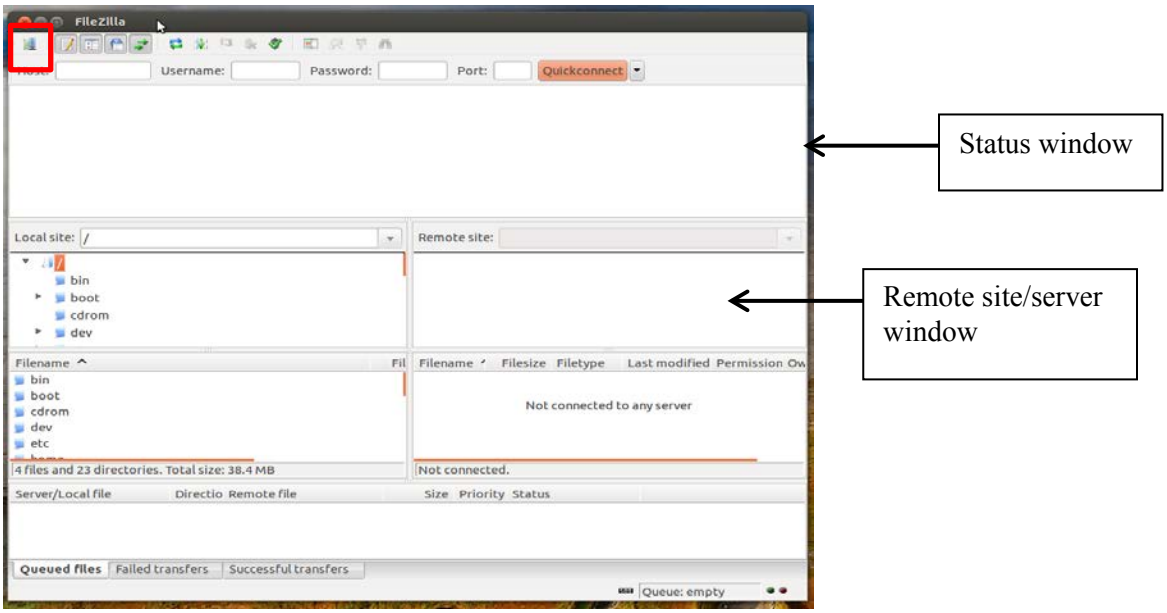


10) The ftp site now shows under "Computer" on the left side of Windows Explorer, and it is possible to copy/paste or click and drag files to this location. Files will be visible after being copied to the ftp site, but refreshing or moving navigating away from the site and back will cause the files to not be visible, even though they have been moved.

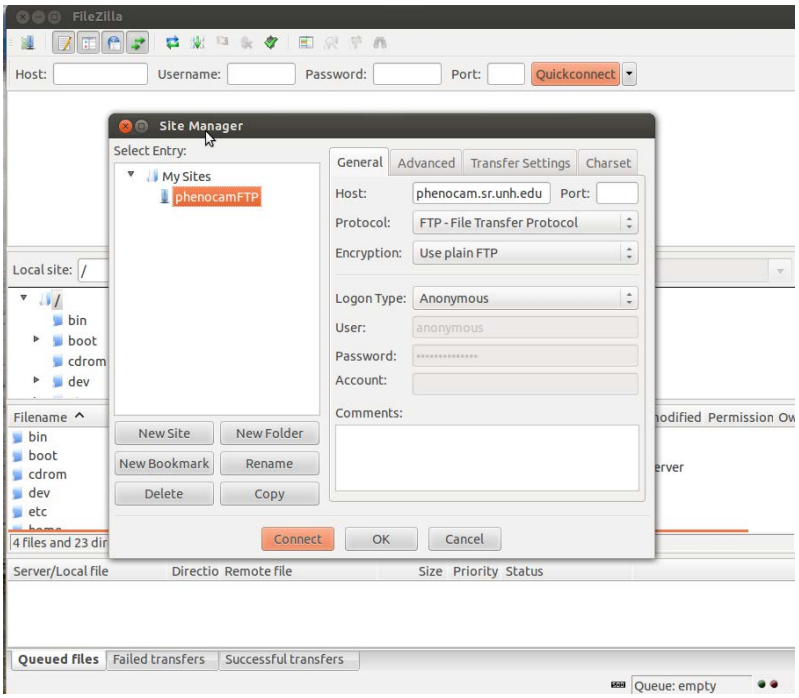
Note that we have imposed limited permissions on these FTP folders, so directory listings using ls and pwd will not work.

Using an FTP client

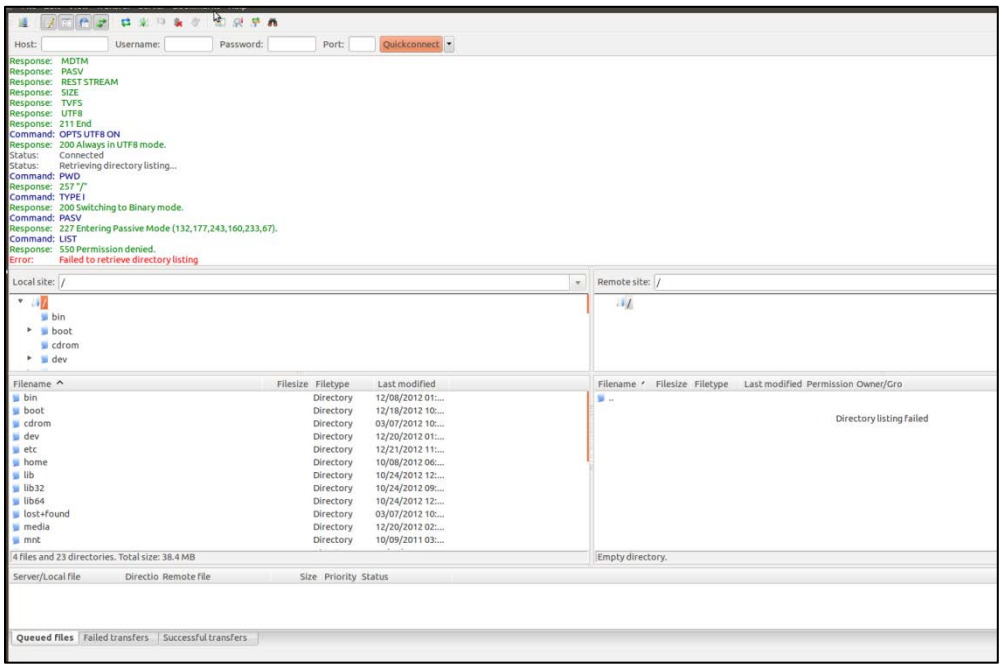
You can also do a manual FTP file transfer using a number of different software programs. We will use the free FileZilla software which you can download at (http://filezilla-project.org/). Here is a screen shot of the program interface:



To create a new connection, click on the 'Site Manager' button in the upper left, highlighted in red above. In the Site Manager, click on the New Site button, which will be listed under My Sites – rename it 'phenocamFTP'. This will be saved for future sessions. Fill out the menus on the right so that they match the configuration below and press Connect:



This will now open a connection to the PhenoCam server. In the status window, you will see some print outs regarding the connection. Normally, you would see the folders and directory listings for the remote server; however, Phenocam is setup to be invisible for security purposes. Therefore, don't be alarmed by the status message, "Error: Failed to retrieve directory listing"

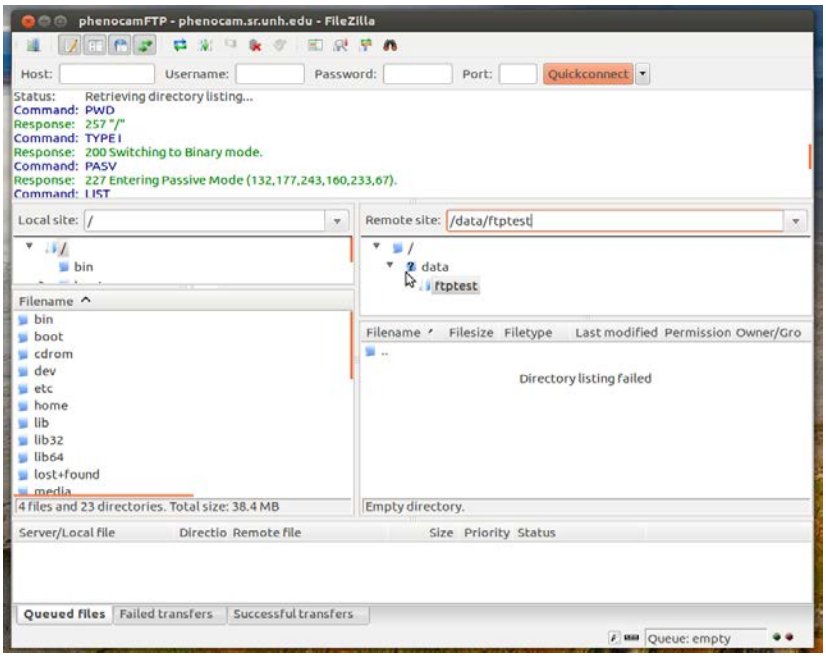


The URL for the ftp directory for your site will be found in the following subfolder:
/data/'sitename'/

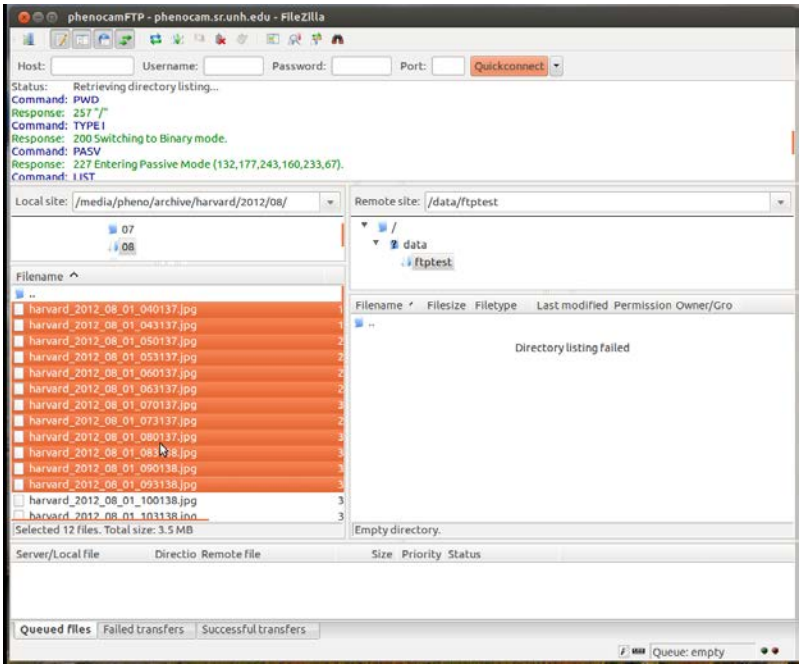
For the purposes of illustrating a transfer, we will just use a test folder called ‘ftptest’, or:
/data/ftptest/

In the ‘Remote site:’ window, enter:
/data/ftptest

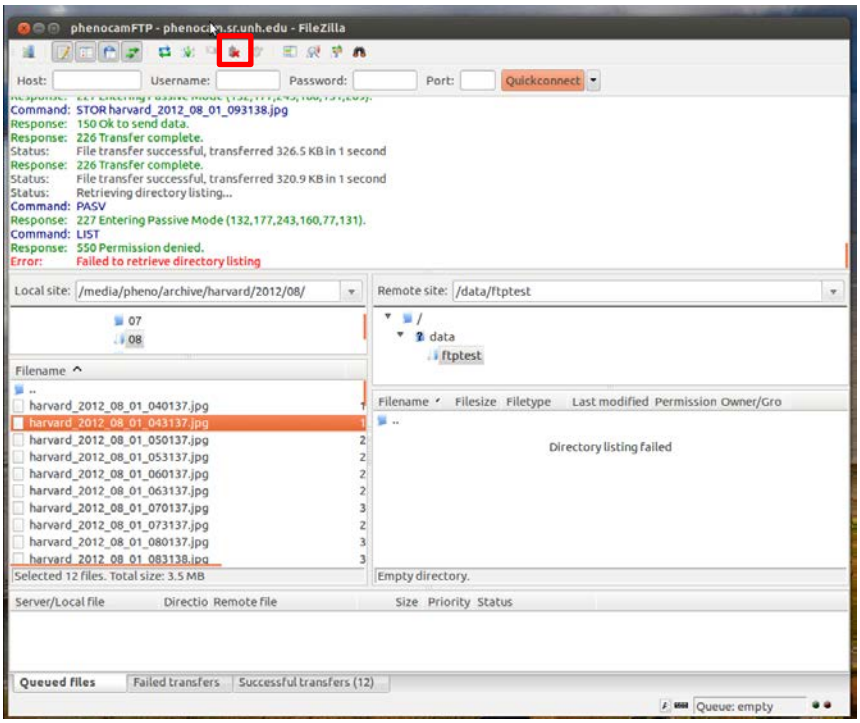
and press Enter. This will create a small directory listing underneath.



In the local site windows on the left, navigate to your own directory containing the photos to be uploaded. Select as many or all photos as are needed and then right click to select the 'Upload' option.



The file transfer should go relatively quickly and there will be status messages for each photo in the status window. Again, because the file listings are locked, you will not see the individual files displayed on the Remote server side.



To sign off, click on the button highlighted in red above.

SOP 12 – Data Analysis and Reporting

Northeast Temperate Network
Version 1.00

Overview

This SOP describes analysis and reporting of long-term phenology data. Phenology data is collected onsite in participating NETN parks by staff and volunteer observers, as well as by automatic cameras and automatic recording units (ARUs). Associated environmental data are compiled from nearby weather stations. Statistical analysis will be performed in the R software package, or an alternative package selected by NETN.

Objectives

Our data analysis objectives are:

- Detect change in timing and abundance of monitored phenophases[1] of key species at index sites in designated core and optional park habitats;
- Explore correlations between phenological data and climate variables (including mean temperature and degree days) in order to develop hypotheses about impacts of climate change on phenology.

Observer Data

Annually, the NETN data manager obtains NPS Northeast Temperate Network data in the National Phenology Database using the online data download tool (at www.usanpn.org/results/data). In the data download menu, go to Partner Organization, select Primary Network to be "National Park Service" in the first box, "Northeast Temperate Network" in the second box, and then add each individual NETN park in the third box. All data from shared, public and private sites within participating NETN parks should be included. If a park or a site seems to be missing from the dataset, that park or site may not be properly affiliated with the NPS NETN network, and the NETN data manager or park coordinator should contact USA-NPN NCO staff[2] to correctly register this affiliation.

In 2014 or later, USA-NPN plans to provide processed data variables including estimated start and end dates for phenophase events, in addition to the raw time series dataset. At that time, NETN will evaluate USA-NPN estimation methods, and decide whether to adopt those methods and use USA-NPN processed datasets for analysis and reporting. For now, NETN will calculate event dates in a simple and straightforward fashion, as follows:

[1] See Appendix A for monitored phenophases.
[2] As of 2013, USA-NPN data contact is Alyssa Rosmartin, alyssarosemartin@gmail.com

In order to avoid bias due to differences between the solar and Gregorian calendar, and precession of the equinoxes, event dates are calculated and analyzed as days past winter solstice (Henebry et al. 2009). For user-friendly reporting, event dates are converted and shown as day of year for a non-leap year in graphs and data summaries. To account for unsampled days between sampling visits, event dates are estimated to occur halfway through the interval prior to recorded date, as described below. Any event date occurring directly after an interval exceeding 7 days in length is discarded from the dataset. When multiple observers are reporting for the same individual, use the first date reported by any trained observer considered as typical or expert, and use observations from all observers to calculate the prior interval.

Phenophase start date:

For each individual plant or animal species monitored at a site, estimate phenophase start date as the first date recorded as "yes" minus the days within the prior interval, divided by two and then rounded down to the last whole number. Prior interval refers to the interval between the previous visit and the visit first recording "yes". Estimate error as the prior interval divided by 2. For example, if "yes" recorded on day 8 was preceded by "no" recorded on day 7, the start date is day 8 ± 0.5 days; if "yes" recorded on day 8 was preceded by "no" recorded on day 6, the start date is day 7 ± 1 day; and if "yes" recorded on day 8 was preceded by "no" recorded on day 5, the start date is day 7 ± 1.5 days.

Phenophase underway:

This event may be a better indicator of ecological impact than start date, and may be less subject to bias. For each individual plant monitored at a site, estimate phenophase underway as the first date that abundance is recorded in the second abundance category (typically the 5-24% or 3-10 category), minus the days within the prior interval divided by two and then rounded down to the last whole number. For each animal species monitored at a site, estimate phenophase underway as the first date that abundance is recorded as any number ≥ 3, minus the days within the prior interval divided by two and then rounded down to the last whole number. Estimate error as the prior interval divided by 2. For example, if the second abundance category recorded on day 8 was preceded by the first abundance category recorded on day 7, the underway date is day 8; if the second abundance category recorded on day 8 was preceded by the first abundance category recorded on day 6, the underway date is day 7; and if the second abundance category recorded on day 8 was preceded by the first abundance category recorded on day 5, the underway date is still day 7.

Phenophase end date:

For each individual plant or animal species monitored at a site, estimate phenophase end date as the last date recorded as "yes" plus the days within the next interval divided by two and then rounded down to the last whole number. Estimate error as the next interval divided by 2. Next interval refers to the interval between the current visit and the next visit. For example, if "yes" recorded on day 7 was followed by "no" recorded on day 8, the end date is day 7; if "yes" recorded on day 6 was followed by "no" recorded on day 8, the end date is day 7; and if "yes" recorded on day 5 was followed by "no" recorded on day 8, the end date is day 6.

Phenophase duration:

For each individual plant or animal species monitored at a site, estimate phenophase duration as the period in days between the start date and end date for that phenophase. For example, if the

start date is day 7 and the end date is day 28, duration is 21 days. Phenophases may have multiple start and end dates during a season. NETN may choose to consider multiple phenophase start and end dates within a season to be a continuous event for a particular phenophase. This may be useful for phenophases which are difficult to detect (i.e., many animal phenophases).

Phenophase peak:

For each individual plant or animal species monitored at a site, estimate phenophase peak as the date corresponding to the midpoint of the interval for which abundance is reported to be the highest value recorded in the current season. Calculate the peak period to include the days in the prior and next intervals, divided by two and then rounded down to the last whole number. Round the midpoint down to the last whole number. For example, if "Open flowers" recorded as >=95% from day 8 until day 28 was preceded by 75-94% on day 6, and followed by 50-74% on day 29, the peak is estimated to be day 17, If this phenophase never reached ≥ 95% in a given year, peak would be calculated on the highest category reached that year. Multiple peaks in a given year complicate this measure – in this case calculate each peak separately. However, if abundance fluctuates only between the highest and second highest categories reached that year, NETN may ignore these minor dips and calculate peak using the earliest and latest dates in which the highest abundance category is reached.

Audio data

Audio recordings are processed using an automatic detection procedure as described in SOP 8-Automated Sound Detection and Classification. The resulting dataset contains a time series of phenophase detections. This audio dataset is essentially continuous, so no adjustment is needed for intervals between sampling dates. For each animal species of interest at an ARU site, relevant phenophase start and end dates are estimated to be the first and last dates on which the phenophase was detected, and phenophase duration is calculated as the period between start and end dates. It is difficult to estimate abundance from audio recordings using automatic detection. NETN may estimate an index of abundance based on calling frequency. However, overlapping calls are problematic and will increase error rates (due to false negatives, but perhaps false positives also.

Camera data

Manual analysis of images from automated cameras aimed at individual plants is recorded and submitted to the National Phenology Database. This dataset resembles observer data, and event dates are calculated as described above for observer data.

Accessing Environmental Data

Weather data for NETN parks is compiled and reported in annual Weather and Climate reports. Weather data are obtained by the NETN data manager from the NPS enterprise weather database[3] in Fort Collins, CO; these data are compiled from weather stations within or

[3] Managed by Brent Frakes.

surrounding the parks. To better understand conditions within each park, gridded Parameter-elevation Regressions on Independent Slopes Model (PRISM) data and Drought Monitor data are obtained from associated internet portals and analyzed for park-specific locations as described in the NETN Weather and Climate reports.

Data validation

During annual training, park coordinators assign a skill classification to each observer. This classification provides a rough measure of confidence in the observer's abilities using a 3-point scale (beginner, typical, or expert); the middle value (typical) is considered the default rating. Unusual observations from observers rated as "beginner," or from untrained observers, may be removed from analysis. The dataset obtained from USA-NPN identifies observers by an identification number assigned by USA-NPN, rather than observer name (for compliance with the Privacy Act). Thus, in order to consider observer skill level in this analysis, park coordinators or NETN staff may need to provide USA-NPN with a list of trained observers with each class, and request a corresponding list from USA-NPN showing the corresponding observer id numbers within each class.

During regression analysis, any outlier event dates with residuals estimated to be greater than or equal to 30 days are considered month mistakes and excluded from data analysis (Schaber et al. 2010). Additional data points that look unusual may be flagged during data analysis for verification.

Descriptive statistics

For selected phenophases of each monitored species (see Appendix S12.A), calculate annual mean and standard deviation of event dates from all individual plants[4] and from all animal sites. For each species, plot the mean event date and SD across years, showing event date on the Y-axis (expressed as day of year for a non-leap year) and year on the X-axis.

For select phenophases of monitored species, illustrate phenophase distribution by plotting the 1) proportion of monitored individuals exhibiting selected phenophases through the current year and/or 2) the recorded abundance of phenophase events through the current year. Show proportion of individuals or abundance classes on the Y-axis, and event date on the X-axis (expressed as day of year for a non-leap year).

For each event date (of an individual plant or an animal species at a site), calculate the difference in days between the mean event date (from the multi-year dataset) and the current year's observation. For selected phenophases of monitored species, plot the difference across years, showing the positive or negative difference (in days) on the X-axis and year on the Y-axis.

[4] We expect our methods to yield sufficient data for analysis of phenology of individual plants; however, if insufficient data exists for individual plants, data may be pooled by species at a site.

Trend statistics

Trend analysis will occur every 5 years after 10 years of data are available.[5] A 20-year dataset is typically regarded as the minimum length for phenological trend analysis, so the 10 and 15 year reports will be preliminary. Trend analysis will be performed using a linear mixed model in the R statistical package (using the lme function in the nlme package) or other software selected by NETN.

To detect trend over time for a specific phenophase event for a species (pooled across sites) or for group of species hypothesized or observed to exhibit similar phenological shifts, regress event date on year. If pooling species, include species as a random effect. For plant phenophases, include individual plant within site as a random effect; for animal phenophases, include site as a random effect. This simple analysis looks only for long-term trend over time to determine if measurable phenological shifts are occurring. If sufficient data from widely spaced parks exist, include latitude as a fixed effect (omitting site if necessary).

Next, to detect trend per degree C or unit growing degree days (GDD), regress event date on average temperature for the 30-day period prior to the event (in degrees C), or cumulative GDD from winter solstice to date of event. For plant phenophases, include individual plant within site as random effect; for animal phenophases, include site as a random effect. If sufficient data from widely spaced parks exist, include latitude as a fixed effect (omitting site if necessary). To calculate GDD for each day from winter solstice to the event, calculate GDD as the average of the daily maximum and minimum temperatures minus the base temperature (10 °C). For example, a day with a high of 22 °C and a low of 11 °C would contribute 6.5 GDDs. Sum these daily contributions to calculate cumulative GDD for the event date.

Reporting

Phenology data are summarized and graphically illustrated in the network's annual Weather and Climate reports. After 10 years of data collection, results of trend analysis will be included in this report.

Literature Cited

Henebry G.M., A.D. Richardson, D.D. Breshears, J. Abatzoglou, J.I. Fisher, et al. 2009. Phenological trend estimation: a reply to Sagarin. Frontiers in Ecology and the Environment, 7: 296.

Schaber, J., F. Badeck, D. Doktor, and W. von Bloh. 2010. Combining messy phenological time series. Chapter 7 in I.L. Hudson, M.R. Keatley (eds.), Phenological Research, Springer, New York.

[5]Pilot data collection began in 2009.

Revision History

Version #	Date	Revised by	Changes	Justification
0.1	Dec 2012	Geri Tierney		
0.2	Jan 2013	Brian Mitchell, Kathy Gerst, Geri Tierney	Added Appendix A. Editorial changes.	
1.00	May 2013	Abe Miller Rushing, Geri Tierney	Replaced “Julian date” with “day of year”. Suggested flagging questionable data points. Adjusted procedure for multiple peaks. Clarified that abundance data will be difficult to extract by automatic detection of audio data. Added error term to event dates	

Appendix S12.A – Selected Phenophases for NETN Species

NETN monitors phenology using phenophases defined by the USA National Phenology Network (USA-NPN). These phenophases vary by species lifeform. Specific definitions of each phenophase are found on species' information sheets, which are available for download from the *Nature's Notebook* website (www.nn.usanpn.org). This program is designed to collect extensive phenological data on 27 core species. To focus data analysis, phenophases shown in bold are selected as the highest priority for data analysis. These selected phenophases are expected to respond most noticeably to changing climate and provide sufficient data for analysis.

Table S12.A.1. Selected phenophases for deciduous trees and shrubs, prioritized for data analysis.

USA-NPN Phenophase	Red maple	Sugar maple	Hobblebush	Beach rose
Breaking leaf buds	**x**	**x**	**x**	**x**
Leaves	**x**	**x**	**x**	**x**
Increasing leaf size	x	x	x	x
Colored leaves	x	x	x	x
Falling leaves	x	x	x	x
Flowers or flower buds	**x**	**x**	**x**	**x**
Open flowers	**x**	**x**	**x**	**x**
Pollen release	x	x		
Fruits	**x**	**x**	**x**	**x**
Ripe fruits				
Recent fruit or seed drop	x	x	x	x

Table S12.A.2. Monitored phenophases for evergreen conifers.

USA-NPN Phenophase	Balsam fir
Breaking needle buds	**x**
Young needles	**x**
Pollen cones	**x**
Open pollen cones	**x**
Pollen release	**x**
Unripe seed cones	x
Ripe seed cones	x
Recent cone or seed drop	x

Appendix S12.A – Selected Phenophases for NETN Species (continued)

Table S12.A.3. Monitored phenophases for wildflowers and forbs.

USA-NPN Phenophase	White wood aster	Garlic mustard	Common milkweed	Rough-stemmed goldenrod	Painted trillium	Bunch-berry	Marsh marigold	Purple loosestrife	Beach pea
Initial growth	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Leaves	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Flowers or flower buds	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Open flowers	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Pollen release									
Fruits	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Ripe fruits	x	x	x	x	x	x	x	x	x
Recent fruit or seed drop	x	x	x	x	x	x	x	x	x

Table S12.A.4. Monitored phenophases for seaweed.

USA-NPN Phenophase	Rockweed (*Ascophyllum nodosum*)
New side branches	x
Receptacles	x
Flat receptacles	x
Smooth inflated receptacles	x
Dotted inflated receptacles	x
Torn receptacles	x

Table S12.A.5. Monitored phenophases for amphibians.

USA-NPN Phenophase	Spotted salamander	Spring peeper	Wood frog
Adults on land	x	x	x
Adults in water	x	x	x
Adults feeding	x	x	x
Vocalizing		**x**	**x**
Mating		**x**	**x**
Fresh eggs	**x**	**x**	**x**
Dead adults	x	x	x

Appendix S12.A – Selected Phenophases for NETN Species (continued)

Table S12.A.6. Monitored phenophases for birds.

USA-NPN Phenophase	Ovenbird	Bobolink	Red-winged blackbird	Winter wren	White-throated sparrow	Common loon	Great black-backed gull
Active individuals	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Feeding	x	x	x	x	x	x	x
Fruit/seed consumption	x	x	x		x		
Insect consumption	x	x	x	x	x		
Flower visitation							
Nut gathering							
Calls or song	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Singing males	**x**	**x**	**x**	**x**	**x**		
Mating	x	x	x	x	x	x	x
Nest building	**x**	**x**	**x**	**x**	**x**	**x**	
Dead individuals	x	x	x	x	x	x	x
Individuals at a feeding station	x	x	x	x	x	x	

Table S12.A.7. Monitored phenophases for Insects – Lepidoptera.

USA-NPN Phenophase	Eastern tent caterpillar	Monarch butterfly
Active adults	x	**x**
Flower visitation		x
Migrating adults		**x**
Mating	x	x
Active caterpillars	**x**	**x**
Caterpillars in tent	**x**	
Caterpillars feeding	x	**x**
Dead caterpillars	x	x
Dead adults	x	x
Individuals at a feeding station		x
Individuals at a light	x	
Individuals in a net	x	x

SOP 13 – Protocol Revision

Northeast Temperate Network

Version 1.02

Overview

This SOP outlines the procedures and deadlines for making changes to the phenology protocol.

Revision Process

NETN staff and cooperators involved in this protocol will teleconference or meet annually in the late fall or early winter to review the prior season's work. Ideally, staff from each participating park and organization (including the Appalachian Trail Conservancy) will participate to convey their park's experience, and any problems encountered. Prior to the meeting, either NETN or park staff will survey volunteer monitors to assess volunteer satisfaction and solicit suggestions for improving the program, including training and data collection

NETN is using USA-NPN protocols for monitoring phenology by observers. NETN staff and cooperators will contact USA-NPN NCO staff annually in the late fall or early winter to discuss any changes for the upcoming year. NETN staff or cooperators will update the protocol annually to reflect changes.

It is also advisable to teleconference or meet annually or every other year with other organizations monitoring phenology in the northeastern US, such as the Northeast Regional Phenology Network, the Appalachian Mountain Club, and the New York Botanical Gardens. Regular communication with these organizations will facilitate collaboration toward regional phenology goals and protocol and data sharing.

Any protocol changes must be completed prior to the annual spring training sessions held at participating parks.

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
1.00	July 2010	Geri Tierney	Adapted from NETN Forest Protocol SOP 1.00	
1.01	April 2011	Brian Mitchell and Geri Tierney	Editorial changes	

1.02	Jan 2013	Ellen Denny, Geri Tierney	Edited references to USA-NPN. Editorial changes.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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